Energy Policy 39 (2011) 1923–1938

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Analysis of a "cluster" strategy for introducing hydrogen vehicles in Southern California

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ARTICLE INFO

Article history:
Received 3 September 2010
Accepted 7 January 2011
Available online 12 February 2011

Keywords:
Fuel cell vehicles
Hydrogen infrastructure
Alternative fuels

ABSTRACT

The cost and logistics of building early hydrogen refueling infrastructure are key barriers to the commercialization of fuel cell vehicles. In this paper, we explore a "cluster strategy" for introducing hydrogen vehicles and refueling infrastructure in Southern California over the next decade, to satisfy California's Zero Emission Vehicle regulation. Clustering refers to coordinated introduction of hydrogen vehicles and refueling infrastructure in a few focused geographic areas such as smaller cities (e.g. Santa Monica, Irvine) within a larger region (e.g. Los Angeles Basin). We analyze several transition scenarios for introducing hundreds to tens of thousands of vehicles and 8–42 stations, considering:

- Station placement
- Convenience of the refueling network
- Type of hydrogen supply
- Economics (capital and operating costs of stations, hydrogen cost).

A cluster strategy provides good convenience and reliability with a small number of strategically placed stations, reducing infrastructure costs. A cash flow analysis estimates infrastructure investments of $120–170 million might be needed to build a network of 42 stations serving the first 25,000 vehicles. As more vehicles are introduced, the network expands, larger stations are built and the cost of hydrogen becomes competitive on a cents per mile basis with gasoline.

1. Introduction

Hydrogen fuel cell vehicles offer the promise of near-zero well to wheels emissions of greenhouse gases and air pollutants, good performance, and a diverse primary resource base. The long-term potential of hydrogen vehicles to address societal problems has been described in many recent studies (National Research Council (NRC), 2004, 2008; IEA, 2008). There is rapid, ongoing progress in development of both fuel cell vehicle technology and hydrogen refueling systems (Garback, 2010). Prototype fuel cell vehicles are reaching goals for range and performance and could be ready for commercialization within 5–10 years (NRC, 2008, 2010). Hydrogen refueling stations based on a variety of near and long-term concepts have been demonstrated. Recent studies by the National Academies (NRC, 2008), and industry (Gross et al., 2007) suggest that hydrogen fuel could be provided at costs competitive with gasoline with mature station technology and larger sized stations (> 500 kg/day).

Although hydrogen and fuel cell vehicles are not yet ready for full scale commercial deployment, they are ready to take the next step toward commercialization. This is widely seen as a pre-commercial rollout in a localized region or "lighthouse city," involving hundreds to thousands of vehicles and an early network of tens of refueling stations (California Fuel Cell Partnership (CAFCP), 2009). Because of California's zero emission vehicle (ZEV) regulation (California Environmental Protection Agency (EPA), 2009), which requires automakers to produce thousands of zero emission vehicles starting in 2012, Southern California has been proposed as an attractive site for this early introduction of hydrogen vehicles and is a major focus of interest worldwide (Melendez and Milbrandt, 2006; NRC, 2008; Greene et al., 2008). At present the only vehicle technologies that qualify as pure ZEVs are battery electric vehicles and hydrogen fuel cell vehicles. Although different automakers are emphasizing batteries or fuel cells, it is likely that a significant fraction of pure ZEVs could be hydrogen fuel cell vehicles. Automakers have announced plans to bring several hundred fuel cell vehicles to California in the next three years and thousands in the following few years (California Fuel Cell Partnership, 2009).

For fuel cell vehicles to succeed, they must have convenient access to hydrogen fuel. Developing a successful early hydrogen refueling network in Southern California, even at the relatively small scale envisioned for the next decade, will require an increased level of hydrogen infrastructure investment. The required investments

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doi:10.1016/j.enpol.2011.01.005

are relatively modest, but industry commitment to the hydrogen alternative is uncertain for two reasons. First, political momentum for hydrogen in the US has declined at the time when larger public and private cooperation is needed. The energy companies, who have been leaders in hydrogen station demonstrations to date, are not subject to the ZEV regulation that applies to the automakers. Second, introducing hydrogen and fuel cell vehicles will require coordination between new hydrogen stations and planned vehicle placements. To proceed, industry stakeholders indicated in workshop discussions that they would need:

- Confidence in the technical success of the H2–FCV alternative, and consensus on a realistic appraisal of current technical status, costs, and timelines for commercialization.
- Clear evidence of a durable, consistent government commitment to the H2–FCV alternative and accompanying policies, throughout a pre-commercial transition.
- A coordinated plan among the major stakeholders on how industry and government can collaborate to accelerate the rollout of H2 and FCVs.
- A long-term business case for hydrogen and fuel cells in a future economy with increasingly stringent carbon policies.

In this paper we analyze strategies for building a hydrogen infrastructure that could address the last two issues. A major question is how many stations to build, what type of stations, and where to locate them. Key stakeholder concerns include cost, fuel accessibility, customer convenience, quality of refueling experience, network reliability, and technology choice.

Automakers seek a convenient, reliable refueling network. Strategic placement of stations is crucial. A positive experience by customers is largely dependent on the convenience of hydrogen refueling compared to gasoline vehicles. Energy suppliers are concerned about the cost of building the first stages of hydrogen infrastructure when stations are small and underutilized. Installing a large number of stations for a small number of vehicles might solve the problem of convenience, but would be prohibitively expensive. Energy suppliers are concerned with how long it would take for hydrogen to reach competitive costs with gasoline, and how to transition through the early phase of uncompetitive stations to a viable business case.

In this paper, a strategy of "clustering" is explored as a way of providing early infrastructure fuel availability with an efficient use of stations at low cost. Clustering refers to the focused introduction of both hydrogen vehicles and refueling infrastructure in a limited number of geographic areas such as smaller cities (e.g. Santa Monica, Irvine) within a larger region (e.g. the Los Angeles Basin). By focusing initial customers in a few small areas, station infrastructure can be similarly focused, reducing the number of stations necessary to achieve a given level of consumer convenience. We evaluate the potential for clustering to improve customer convenience, reduce refueling network costs, and enhance system reliability by providing redundancy in case of stations being unavailable, for example because of equipment failure.

We analyze a variety of "clustered" scenarios for introducing hydrogen vehicles and refueling infrastructure in Southern California over the next decade, to satisfy the requirements of the California ZEV regulation. Through a series of interviews with expert stakeholders in the automotive, energy and fuel cell industries, we developed scenarios for FCV numbers, hydrogen demand, station placement, and numbers of stations in Los Angeles, in three 3-year time periods: 2009–2011; 2012–2014; 2015–2017 (Nicholas and Ogden, 2010).

We assume vehicles and stations are placed in 4–12 "clusters" identified by stakeholders in the CAFCP study (CAFCP, 2009) as early market sites (Fig. 1). Connector stations are added to facilitate travel throughout the Los Angeles Basin.

For each scenario we estimate:

- Station placement within the Los Angeles (LA) Basin
- Convenience of the refueling network (travel time to the nearest station)
- Economics—capital and operating costs of stations; cost of hydrogen for different station scenarios.

We also discuss transitional strategies for the choice of hydrogen supply pathways, as the network expands. A transitional cash flow analysis is carried out to illustrate the investments that might be needed over time to bring hydrogen fuel to cost competitiveness with gasoline.

A key idea advanced in this paper is that by concentrating both early vehicles and stations in a relatively small number of clusters within a larger geographic area (the LA Basin), it is possible to provide convenience and reliability approaching that of gasoline with a small number of strategically placed stations, and at relatively low cost. As more vehicles are introduced, the network expands from this initial basis, larger stations are built and beyond 2017, the cost of hydrogen becomes competitive on a cents per mile basis with gasoline.

Clearly, there are challenges and risks inherent in introducing any radically new vehicle technology such as fuel cells, and new fueling infrastructure such as hydrogen. Key technologies notably fuel cells, are still developing and coordination of stakeholders is not assured. This paper should not be considered a prediction of the future, but rather a plausible scenario for how infrastructure might be built, assuming technical success and a decision to proceed rapidly toward full commercialization.

2. Rollout scenarios for hydrogen and fuel cell vehicles in Southern California

To develop realistic rollout scenarios that account for major stakeholders' differing viewpoints and goals, we conducted a series of interviews with automakers (Toyota, Daimler, Honda, General Motors), energy companies (Shell and Chevron), fuel cell industry groups (the California Fuel Cell Partnership), and California state regulators (California Air Resources Board, California Energy Commission). Each stakeholder was asked its perspective on how an early hydrogen transition might unfold in the Los Angeles area over the time period 2009–2017 with respect to:

- Potential numbers and placements of hydrogen fuel cell vehicles over time
- Potential hydrogen demand for these vehicles
- Station placements (number of stations, size and location) within the Los Angeles area to support fuel cell vehicles
- Types of hydrogen stations ("fixed" versus mobile; station technology choice)
- Costs for hydrogen stations (current and future)

2.1. Numbers of hydrogen vehicles and hydrogen demand

It was generally agreed by all the stakeholders that the California Fuel Cell Partnership's 2008 survey of industry stakeholders (California Fuel Cell Partnership, 2009) was the best current estimate for potential numbers of hydrogen vehicles in Southern California between 2009 and 2017, and associated hydrogen demand. Our scenarios assume:

- 2009–2011. A total of 636 fuel cell vehicles will be placed in Southern California. This is based on announced plans by the