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Decentralized refueling of compressed natural gas (CNG) fleet vehicles in Southern California☆

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ABSTRACT

While some compressed natural gas (CNG) vehicle fleets have a station at their base for central refueling, others lack refueling capability at their fleet depot and must rely on publicly available stations. To understand this kind of decentralized refueling behavior, we surveyed 133 drivers of CNG fleet vehicles at six public stations across the Los Angeles region. Nearly one-third of CNG fleet drivers were solely reliant upon public refueling for their operations. For each driver's refueling trip, we used GIS to compare the chosen station's proximity to the driver's fleet base and their deviation from the shortest path between their previous and next stops relative to all other stations they could have chosen. This revealed-preference approach shows that fleet drivers chose the station with the smallest deviation over the station closest to base by a 6:1 ratio, though this ratio varied by the driver's availability of central refueling and type of vehicle and route. Given that public stations remain essential to meeting decentralized refueling demand for other fleets as well as consumers, these findings have important implications for fleets that are both considering the adoption of CNG vehicles and the additional investment of hosting central refueling infrastructure at their base.

1. Introduction

In the United States, the nearly singular reliance on petroleum fuel in the transportation sector carries a host of environmental, economic, and social issues. Major automakers now produce vehicles capable of operating with electricity, hydrogen, compressed natural gas (CNG), and biofuels, offering potential economic stability, improved air quality and health, carbon emissions reductions, and domestic energy production. From a policy standpoint, commercial vehicle fleets are often recommended as a more promising initial market foralternative fuel vehicle (AFV) adoption than personal vehicles for several reasons (Nesbitt and Sperling, 2001; Melendez, 2006; Zhao and Melaina, 2006; Corts, 2010), although the universality of some of these generalizations have been questioned (Nesbitt and Sperling, 1998):

1. government incentives and mandates are more easily implemented with private and government fleets
2. auto manufacturers can work directly with fleets
3. in-house maintenance staff can be trained and equipped for the new vehicle technologies
4. central refueling can ease range anxiety
5. commercial vehicles, which typically drive twice as many miles and get fewer miles-per-gallon, use more fuel per year

The focus on fleets has been especially important to researchers and policy makers in the context of “energy transition” analysis, which emphasizes the process of and barriers to shifting away from the current petroleum-based system to one based on alternative fuels (Ogden, 1999; Greene et al., 2008). This transition requires many essential parts of the “business ecosystem”—vehicle production, fuel production, fuel distribution, laws, standards, taxes, insurance, education—to evolve in a coordinated fashion (Melendez, 2006; Lu et al., 2014). At the core of the transition problem is the so-called “chicken and egg” problem, the phenomenon of hesitancy that exists between AFV manufacturers and AFV station owners in which each is reluctant to invest before the other does (Melaina and Bremson, 2008). A key strategy for breaking this cycle has been to develop large anchor fleets of private, state, or federal vehicles co-located with a depot-based fuel station (Melendez, 2006). The “fleets-first” strategy is for anchor fleets to provide an initial market for AFV manufacturers, and for central refueling by the fleet to provide stable demand for the first fuel stations. By placing pumps “outside the fence,” anchor fleet stations help to seed an initial publicly available refueling infrastructure for other fleets and

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eventually consumers. In surveys conducted by Melendez (2006), experts at National Renewable Energy Laboratory and Clean Cities Coordinators viewed the fleet introduction strategy as critical, though not sufficient by itself to spur widespread consumer adoption.

Legislation geared toward increased AFV adoption in the United States began with the Alternative Motor Fuels Act of 1988, which provided incentives to manufacturers to produce the vehicles. The Energy Policy Act of 1992 (EPACT) then required federal and state fleets to deploy certain numbers of AFVs. Some 13 years later, Section 701 of the Energy Policy Act of 2005 (EPAct § 701) stipulated that federal agencies with dual-fuel vehicles should operate with an alternative fuel when stations are accessible and the fuel is not unreasonably more expensive than gasoline. These and other policies, combined with heightened air quality standards and increasing availability, variety, and competitiveness of vehicles, have led to an increase in AFV fleets operating in recent years.

Nearly 23% of the national bus fleet now operates with natural gas, an increase of about 5% since 2010 (American Public Transportation Association, 2017). Total U.S. natural gas vehicle fuel consumption has increased 44% since 2010, with 2016 representing the highest total volume of natural gas used in transportation on record (EIA, 2017). In California, there are now approximately 24,600 natural gas vehicles in operation, half of which are classified as medium- or heavy-duty vehicles that belong to vehicle fleets (Schroeder, 2015). Although CNG vehicles are not often dual-fueled, some fleets have turned to natural gas in particular because of its relatively low cost, lower price volatility, reduced maintenance, competitive driving range, familiar technology, lower emissions relative to liquid petroleum-based fuels, and in many regions, high-occupancy vehicle lane access (AFDC, 2017; NGV America, 2017; Questar, 2017).

The recent proliferation of CNG vehicles in operation has been supported by a corresponding increase in stations nationwide from 841 in 2010 to 1700 as of April 2017 (AFDC, 2017), many of which were largely built to facilitate CNG fleet travel. Of the 1700 CNG stations nationwide, 55% are available for public use. Nearly one-third of these 942 stations are owned by state and local governments or utilities. The other two-thirds of the public CNG stations are owned by private developers, and may or may not have a fleet anchored at the station. These public stations support decentralized refueling for a variety of fleets, though it remains unclear to what degree fleets rely upon them for their daily operations. The remaining 45% of U.S. CNG stations are not open to the general public, and instead are dedicated to specific users.

This study aims to address the gap in knowledge about where CNG fleet drivers refuel when they do so away from their fleet base. Based on intercept surveys of 133 CNG fleet drivers using the public CNG refueling infrastructure in the greater Los Angeles area, we ask the general research question: how do AFV fleet drivers access public CNG refueling stations in Southern California? Specifically, to what degree do fleet drivers prioritize such stations near their fleet base, and are there differences in this behavior between drivers without central refueling compared to those that have it? Additionally, are there variations in how drivers access these stations based on the nature of the vehicle or route type? Buses, taxis, delivery shuttles, municipal vehicles (such as those for trash collection), and mail and parcel distribution routes all differ in daily travel patterns and trip frequency.

The purpose of our study is to analyze the differences in usage patterns for fleet drivers that rely on public AFV stations in large cities, which is an important topic for location modellers, station developers, fleet operators, and policy-makers. Results from this analysis have relevance to current policies regarding the use of alternative fuels in government vehicle fleets, along with commercial considerations important to deciding the locations of CNG stations. We then discuss the relevance of such public AFV stations that allow for fleets to operate with alternative fuels in an urban environment. This is of particular importance because city and regional governments consider AFVs to be a critical means to comply with air quality standards and greenhouse gas emissions policies.

2. Literature review

With the increase in fleet adoption of AFVs, several studies have analyzed AFV fleet travel patterns and driver and fleet manager perceptions and practices. Nesbitt and Sperling (1998) critically examined seven myths associated with the fleets-first strategy. In contrast to traditional perceptions, they found that very few fleets relied exclusively on central refueling at their base. Heterogeneity of fleets has been another theme: Nesbitt and Sperling (1998) highlighted the diverse nature of fleets and the types of routes driven, while Nesbitt and Sperling (2001) contrasted different organizational decision-making structures for fleet purchases. Flynn (2002) found that limited refueling infrastructure was the biggest barrier to CNG fleet development in Canada in the 1980s. According to Golob et al. (1997), fleet operators in Southern California considered off-site refueling to be a critical factor in their willingness to invest more aggressively in AFVs. Johns et al. (2009) studied bi-fuel vehicles operated by a county forest preserve and found that the vehicles were often filled with conventional rather than alternative fuels, depending on refueling convenience.

These few studies on AFV refueling by fleets suggest that: central refueling cannot satisfy all fleet refueling needs, convenience of public refueling infrastructure is important, and usage of the public stations may vary by type of vehicle, route, and company. To construct an effective refueling infrastructure for fleet AFVs, a deeper understanding is needed of refueling patterns by fleet drivers and, specifically, which stations drivers choose when they refuel away from their base. A limited amount of research along these lines has been conducted on consumers driving private automobiles.[1] In two pioneering intercept surveys at diesel and gasoline stations by Sperling and Kitamura (1986) and Kitamura and Sperling (1987), consumers cited proximity to home and lower fuel price as reasons for choosing a refueling station, although they stated that high-traffic commuting routes between home and work locations could be good candidate sites for early refueling infrastructure because a high percentage of drivers refueled on commuting trips. Plummer et al. (1998) also conducted revealed preference surveys of gasoline refueling in Minnesota, showing that consumers rely on a set of several stations, some of which are not near their homes. Bunzeck et al. (2010) found that 74% of consumers in Netherlands fill at gasoline stations within 10 min from the start of their trips. They also asked about their preconditions for refueling availability for switching to hydrogen fuel-cell vehicles, with nearly half stating that stations would have to be sufficient to travel abroad or at least travel across the Netherlands.

Two papers report on the revealed preference for refueling station choice by consumers driving CNG vehicles. First, Kuby et al. (2013) conducted intercept surveys at CNG and nearby gasoline stations in Southern California and found that CNG drivers refuel farther from home, farther off their shortest travel-time paths, and more frequently during the middle part of a trip than drivers of gasoline vehicles. In the second paper, Kelley and Kuby (2013) further investigated the behavior of these CNG drivers to determine what a driver's choice of refueling station on a given trip indicates about what they considered more convenient: a station close to home or one on their way. They used GIS to estimate the distance and travel time from home and the degree of detour off the fastest origin-destination route for all possible stations a driver could have chosen. The analysis showed that when no station existed that satisfied both criteria and drivers are thus forced to choose between these two definitions of convenience, consumers chose the CNG station on the way over the station closest to home by a 10:1 ratio.

[1] In this paper, we use the term “consumer” to indicate individuals driving a household vehicle, in contrast with fleet drivers driving commercial or government vehicle.