An insight into potential early adopters of hydrogen fuel-cell vehicles in Japan

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Abstract

With the inauguration of the world's largest green hydrogen facility, the Government of Japan is steadily advancing towards its goal of transforming into a hydrogen-based society, but the lack of interest in adopting hydrogen fuel cell vehicles (HFCVs) among consumers is noticeable. This study examines the socioeconomic profiles of 500 potential car buyers with and without interest in HFCVs. The results show that the potential early adopters of HFCVs exhibit similar trends of sex, employment status, number of people in the households, weekly distance traveled, and frequency of using expressways that influence their decision. They have a significant variance in income, previous battery electric vehicle (BEV) experiences, and knowledge of HFCVs. The results suggest that knowledge of HFCVs and related technologies, and previous experience in driving BEVs encourage respondents to purchase HFCVs. The study suggests that the greater awareness of HFCV can assist policymakers in the successful market adoption.

Keywords: Hydrogen fuel-cell vehicles; potential early adopters; market adoption.

Introduction

The energy crisis following the Great East Japan Earthquake and Tsunami in 2011, which caused the Fukushima Daiichi nuclear disaster, was the main driving force for Japan toward the realization of a Hydrogen Society. The concept of the Hydrogen Society was endorsed in the fourth Strategic Energy Plan in 2014, with the aim to reduce dependency on fossil fuels and expand renewable energy. The Council for a Strategy for Hydrogen and Fuel Cells revised the fourth strategic roadmap on hydrogen in 2016 with an emphasis on green hydrogen. In 2017, Japan became the first country to adopt a basic hydrogen strategy, and subsequently, Tokyo Statement 2018 was released following the world's first Hydrogen Energy Ministerial Meeting to promote cooperation and the deployment of hydrogen technologies. In the revised plan in 2016, the Ministry of Economy, Trade and Industry (METI) targeted 40,000 HFCVs by 2020, and 800,000 by 2030 from 400 HFCVs on Japanese roads at that time [1]. In the wider context of a national objective to lead the world in hydrogen and fuel cells, Japan, the EU, and the US at the G20 Osaka Summit 2019 signed a joint agreement to explore the use of hydrogen and fuel cells [2]. In the same year, the Second Hydrogen Ministerial Meeting observed the global goal of developing a wide network of hydrogen refueling infrastructure, along with efforts to increase public awareness about hydrogen mobility.

The hydrogen fuel-cell vehicle (HFCV) runs on pressurized hydrogen from a hydrogen refueling station, emitting only water vapor from its exhaust. It can be filled as quickly as a conventional vehicle, in less than five minutes, and offers a comparable driving range to the conventional fuel and purely electric vehicles. In the advantages for HFCV users, BMW [3] mentions quick recharging time and longer range as a major edge of this technology over other fuel technologies in the market. In the biggest shortcoming of adopting hydrogen cars, they mentioned the lack of well-developed re-fueling infrastructure [3]. Several economies around the world, including Japan, South Korea, the US (California), and Germany, are backing the use of hydrogen as a fuel in the transportation sector by investing substantially in hydrogen infrastructure and commercial rollouts of HFCVs, and by introducing governmental incentives for the successful penetration of this fuel technology. By far, Japan has remained a global leader in hydrogen and fuel cell technology, and a vocal advocate of a hydrogen-based society.

Japanese automakers Toyota and Honda stand out for their commitment to a successful commercial rollout of HFCVs. In 1996, the first Toyota concept HFCV was debuted in Osaka, paving the way for the automaker to draw consumers' attention to fuel cell technology [4]. Toyota Mirai was the world's first commercially available HFCV and was unveiled at an auto show in Los Angeles in 2014, with a range of 500 km per tank [5]. Soon after Toyota

started mass producing its landmark HFCV, other automakers announced their rollout plans for hydrogen vehicles. In 2018, 11 Japanese companies, including automakers, oil and gas giants, and investment banks, formed Japan H2 Mobility (JHyM), which was aimed to lower the cost of building hydrogen refueling stations (HRSs) and to bring an addition of 80 new HRSs by 2021 all across Japan [6].

Japan remains at the forefront of the hydrogen revolution through technological advancements in hydrogen and fuel cells, with ambitious plans being implemented for the successful adoption of this technology into the market. As such, Japan is keen to showcase hydrogen as a fuel for the future by using 100 fuel cell buses and 500 HFCVs during the upcoming Tokyo Olympics in 2021 [7]. The Government of Japan is focused on increasing public awareness about and accessibility of HFCVs, with Japan having the largest network of HRSs in the world. Market penetration of this technology is still challenging, as there are only approximately 4,000 HFCVs on roads in Japan as compared with the initial target of 40,000 vehicles by 2020 [1].

Without public support, HFCV proliferation seems far away and raises questions on the practicality of the Japanese goal of becoming a hydrogen-based society. Most previous studies carried out in the EU and the USA highlighted barriers to the successful deployment of these environmentally friendly vehicles. The literature points out the high upfront cost, uncertainties about benefits, lack of awareness and information, lack of refueling infrastructure, safety concerns, limited recharging options for HFCVs, source of hydrogen, vehicle performance, industry development, diversity in vehicle models and size, and barriers to the adoption of HFCVs [8–15].

In the past, policymakers in Japan have focused on addressing these barriers by recommending huge investments in the hydrogen infrastructure for import and domestic distribution, and research and development (R&D) to reduce the cost of fuel cells in a bid to diminish the price difference between the HFCV and other comparable zero emission vehicles. These efforts led Japan to become the global leader in hydrogen fuel-cell technology and related industries. However, limited research has been carried out to explore users' perspectives on these vehicles in Japan.

The success story of hybrids raised public awareness about the importance of reducing greenhouse gas emissions (GHGs) in the transportation sector. Soon after its commercial launch in 2009, Nissan Leaf, a pure battery electric vehicle (BEV), became one of the most eminent electric vehicles in the world in 2010. Early adopters helped in the successful penetration of these environmentally friendly vehicles. In contrast to other automobile technologies in the market, HFCV technology is yet to successfully penetrate the domestic market in Japan. Thus, it is crucial to

understand the characteristics of consumers who may adopt HFCVs as potential early adopters and can assist in the successful penetration of HFCVs into the market.

The Japanese market is particularly relevant for investigating consumers' attitudes and governmental policies to successfully diffuse HFCVs. This study makes two important contributions to the Japanese literature on HFCV adoption studies.

1. A systematic literature review exploring Japanese literature on HFCV adoption and exploratory studies from other geographic markets.

2. A non-probabilistic purposive sampling of data representing consumers who are potential car buyers.

Currently, Japan has the largest network of HRSs in the world, with a total of 127 hydrogen stations operating across the country, followed by Germany (81), US (California (64)), South Korea (34), and China (61) [16–22]. Figure 1 shows the status of HRSs in operation as of 2019, and planned HRSs according to country-specific hydrogen roadmap strategies.

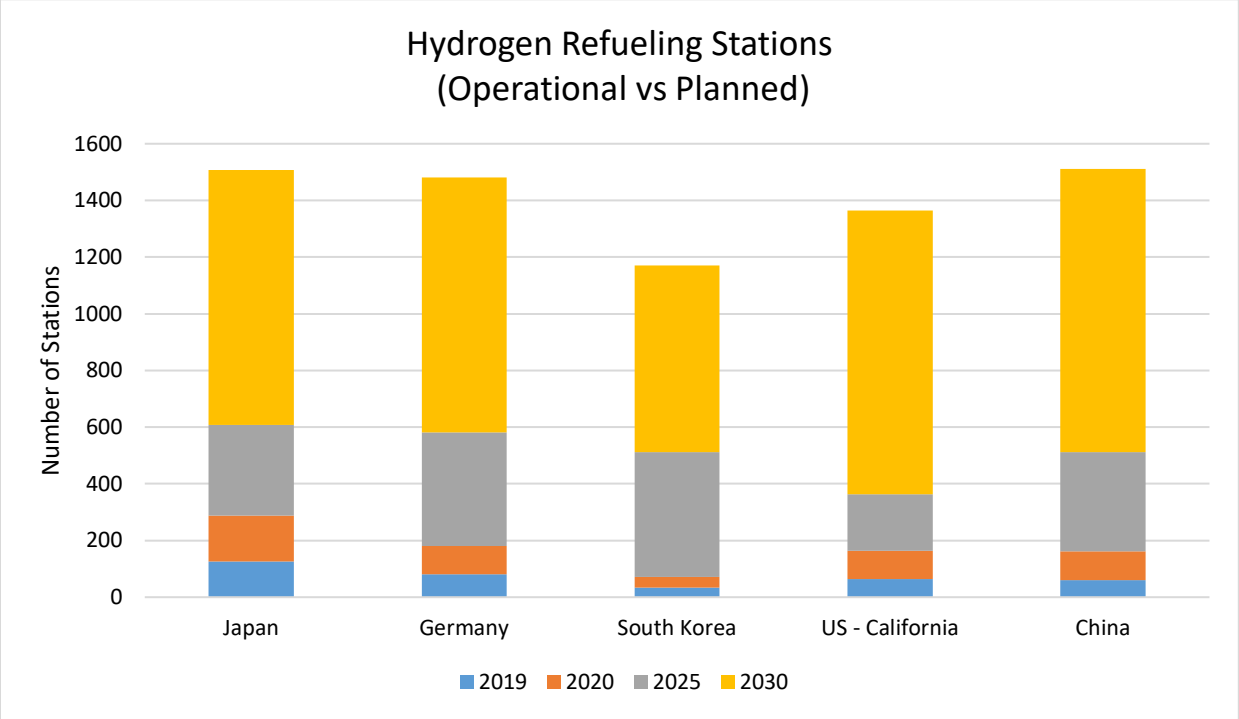

Fig. 1 Current and planned number of hydrogen stations worldwide. Source: [16–22].

Reportedly, for public acceptance of HFCVs, the availability of a sufficient network of hydrogen stations providing cheap hydrogen is considered an important factor in the public uptake of this fuel technology. Previous studies highlighted the lack of hydrogen-refueling infrastructure as the main bottleneck in the successful adoption of HFCVs [9,23–28]. In the empirical study by Li et al. [29], the findings highlight the positive impact of the refueling accessibility that can promote customers adopting HFCVs. Greene et al. [30] linked the substantial market success of the hydrogen vehicles with the availability of the refueling infrastructure. Recently, Japan inaugurated the world's largest green hydrogen production facility Fukushima Hydrogen Energy Research Field (FH2R), which can refuel 560 HFCVs a day. Despite the existence of world's largest hydrogen re-fueling stations infrastructure, HFCV sales are still struggling to meet the initial targets in the Japanese market. Whereas the number of HFCV units sold only in the California State in the same period after the initial release of commercial HFCVs are more than in the Japanese market. Figure 2 shows the number of HFCV unit sales in different markets. As of March 2020, there were approximately 8,000 HFCVs in the US, which was more than any other geographic market in the world. The Clean Vehicle Rebate Project (CVRP) and stringent zero emission vehicle (ZEV) regulations in California, US, are the driving forces behind the rapid increase in the deployment of ZEV technologies, such as hydrogen fuel cells and BEVs.

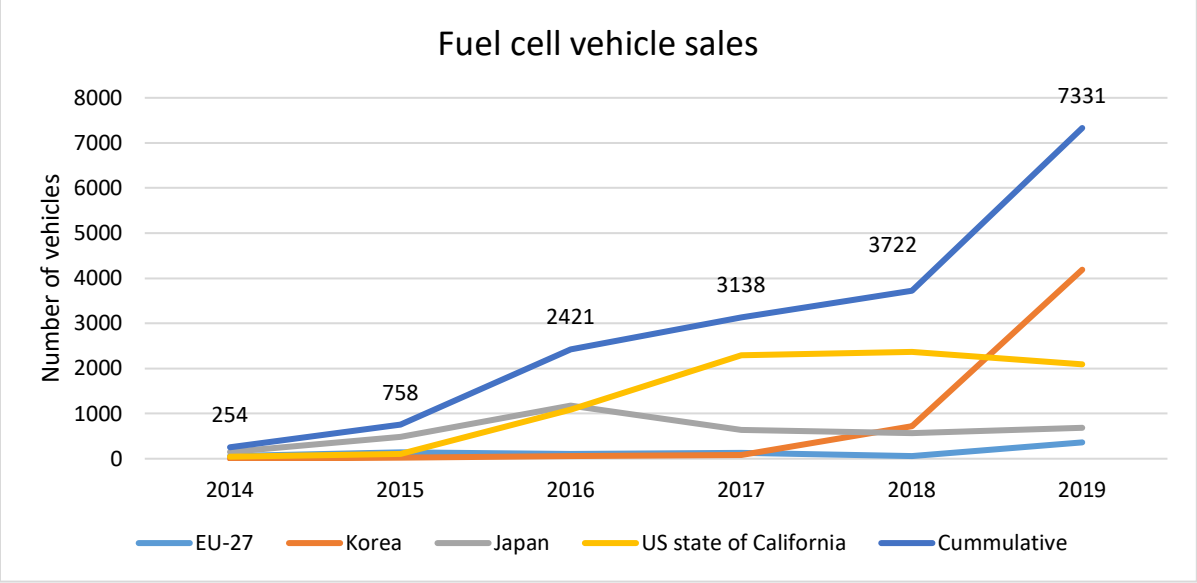

Fig. 2 Global hydrogen fuel-cell vehicle yearly and cumulative sales from 2014–2019. Source: [16–22].

In an attempt to understand this contrast, we examined the socioeconomic profiles and attitudes of potential early adopters of HFCV. Rogers [31] categorizes consumers into five classifications: Innovators, Early adopters, Early majority, Late majority and Laggards. For any new technology, successful diffusion into the market is dependent on the adoption by innovators and early adopters. These two groups are different from the consumer segments who make up the mass market. These two groups are collectively denoted as the early adopters. Successful penetration of hydrogen fuel cell vehicles in the Japanese market is also contingent on the adoption by the early adopters. For this study, we used the term in a more rational way and referred it for the respondents who are interested in HFCV to buy in the next two years.

The literature on the Japanese market focusing on the socio-demographics of potential HFCV early adopters is very limited, and this study is the first of its kind in Japan focusing on consumers who will guide the market entry of this fuel technology. Thus, the primary objective of this study is to fill the present significant research gap on potential HFCV early adopters in Japan. Our empirical study will guide researchers and policy makers in Japan a foundation for follow-up investigations into consumer's socio-economic attributes linked to HFCVs. Some of the earlier studies on socio-demographics of potential buyers of hydrogen fuel vehicles have been conducted in the US, and Europe.

The focus of this study is Aichi Prefecture, which is home to the production line of Toyota's "Mirai" HFCV, and has the highest number of passenger HFCV ownership as well as total vehicle ownership among all prefectures in Japan. In an attempt to promote HFCVs, "Toyota Mirai" has remained the official vehicle for the Aichi Prefectural Government. Our previous study [32] investigated the impacts of policy measures on purchase intentions for HFCVs. The objective of the current study is to shed light on the sociodemographic characteristics of potential early adopters of HFCVs and to identify the main drivers for such a purchasing decision in Japan. In particular, the focus of the current paper is on the interest in purchasing and using hydrogen vehicles, which is a prerequisite for the intention to purchase. This paper identifies the segments that are interested in purchasing and using hydrogen vehicles.

Literature Review

The previous literature on the successful entry of disruptive technologies into the market signifies the importance of studying the profile of the early adopters who will be adopting them. Hardman et al [33] termed hydrogen vehicle as a disruptive technology trying to enter into the competitive and well-established auto-market. In their findings, the authors conclude that the hydrogen vehicles should be targeted to niche markets in a bid to get early market success.

Scholarly articles and exploratory studies in different countries mention the ambitious targets based on forecasting models that show the successful market entry of hydrogen vehicles by 2030 or 2050. Rosenberg et al [34] mentioned the possibility of transition to hydrogen fueled transportation by 2025 in Norway. In the modelling analysis, their results depict the full-scale penetration of HFCVs by 2035 in the urban areas. Some researchers highlight the role of governmental policies for the market entry of green fuel cars. Fan et al [35] focused on the greater importance of governmental policies in the successful market entry of new energy vehicles including hydrogen and BEVs more than the role of socio-demographics of the individuals who adopt these cars at earlier stages.

The influence of socioeconomic factors on the adoption of alternative fuel vehicles (AFVs) is paramount, and most of the previous studies have found a relationship between demographic factors and interest in AFVs. Studies show that younger, well-educated and middle-aged individuals, homeowners, multiple vehicle owners, and males were likely to adopt BEVs and PHEVs [36–48]. Most of the earlier investigations incorporated the stated preference approach [48–52], qualitative interviews [54–56], design games [57], and by directly interviewing consumers who have experienced in using BEV and PHEVs [58–60]. In one of the review study on the potential lead markets for HFCVs in 2030 and 2050, the authors underline the significance of the demographics, and social factors as a driver in the early-adopter markets of this fuel technology [61]. Ajanovic and Haas [62] analyzed the pivotal barriers to the increasing use of hydrogen in the energy sector and HFCVs. In their investigation, the authors linked the impediment in the full-scale adoption of HFCVs with the lack of regulations and the coordination between the stakeholders.

These investigations assist policymakers in understanding consumers' preferences, attitudes, and knowledge of these vehicle technologies. Research on the socioeconomic profiles of early adopters of these vehicles revealed the profile of the actual buyer.

Studies on HFCV adopters in EU and the US

Hardman [63] investigated the socioeconomic profiles of 906 HFCV owners in California and compared them with 12,910 BEV-owning households, in a bid to examine the differences or similarities, if any. The study found no significant difference in the HFCV- and BEV-owning households in terms of socioeconomic profile characteristics such as income, education level, number of people in the household, number of vehicles in the household, and sex. However, the study did find a few differences. That is, HFCV households were slightly older than BEV-owning households, were more experienced in using AFVs (BEV, PHEVs/HVs), have traveled longer commutes, and owned fewer houses. Education and income demographics of early adopters of HFCVs who were recruited for a thematic

content analysis study by Jaramillo et al. [64] were in line with the HFCV drivers who applied for rebate under the California vehicle rebate program (CVRP). Approximately 50% of the respondents attained a post-graduate degree, and 33.3% reported having a household income of more than US$ 200,000.

Hardman and Tal [65] conducted an online questionnaire survey on 470 HFCV owners and 1550 BEV owners in California to explore the socioeconomic profile, travel patterns, and attitudes of early adopters of HFCV buyers and compared them with the BEV households. HFCV households were associated with higher incomes, higher education levels, and middle-aged males owing to the higher number of vehicles. The study found consistency of HFCV owners with the demographic profile of BEV households. The study conducted by Hardman et al. [11] to assess consumer attitudes toward HFCVs represents the profile of 30 respondents who drove Hyundai FCV at an event in the UK. The socioeconomic profile of respondents was congruous with the anticipated profiles of early adopters from the innovation theory [66].

Ozaki et al. [67] conducted a survey of Toyota Prius buyers in the UK to examine the characteristics of the buyers of the HVs. Interestingly, the majority of Toyota Prius vehicle owners in his study were men in their 50s and above, with a net yearly income of over US$ 80,000 and owning multiple vehicles. Findings of the international project AcceptH2 highlighted the support of hydrogen and fuel cells in five different cities: London (UK), Luxembourg, Berlin (Germany), Perth (Australia), and Oakland (California, USA). The study reported that the knowledge about hydrogen and fuel cells is generally low; males and people with higher education levels tend to have more knowledge about hydrogen technologies than females and people with lower education [68]. Martin et al. [69] evaluated HFCV drivers' response in a "ride and drive" clinic series with 182 respondents in California. The respondents reported having higher education and higher income, and were mostly males, unmarried, and younger than either the US or Californian populations. Almost 95% of the respondents expressed either a positive or very positive impression of the HFCV.

The determinants of knowledge and acceptability of HFCVs among Londoners were investigated through a socioeconomic survey of 414 respondents. Nearly 60% of the sample was composed of female respondents, and reportedly the education level and household income were higher when compared to the London average. Prior awareness of hydrogen technology was termed as the key determinant of acceptability, and hydrogen awareness was associated with education level, age, sex, and environmental knowledge [70]. Zimmer and Welke [71] studied the public acceptance and awareness level of the hydrogen vehicle in Germany. The results found almost 80% of the Germans were in favor of seeing hydrogen vehicles on German roads. In the interviews, they found the general

public's concern on the production of hydrogen from renewable sources. The lack of knowledge and awareness of hydrogen applications was the main factor emerged from the study findings.

Haraldsson et al. [72] found a strong correlation between age group and the need to learn more about hydrogen technology in an attitudinal survey study in Stockholm, Sweden. Age groups 40 and older seemed more interested in receiving further information on this technology. The study by Molin [73] revealed that male and higher educated respondents had more knowledge of hydrogen than females and lower educated respondents. A contingent valuation study on driving HFCVs by Mourato et al. [74] reported environmental considerations as a detrimental factor in a long-term vehicle purchase decision.

Studies on HFCV adopters in Japan

Trencher et al. [75] examined policy measures taken by the public and private sectors in Japan to accelerate the diffusion of HFCVs. Hienuki et al. [76] investigated the acceptability of hydrogen energy technology through a survey conducted in 2016–2017 on participants who attended hydrogen technology seminars and events in Yokohama, Japan. Their study found that an individual's acceptability of a new technology is not entirely dependent on environmental concerns and socioeconomics. The results of the opinion survey administered in 2017 suggest that risk information tends to increase the acceptance level for the H_2 infrastructure [77]. Yoshida [78] concluded that Japanese consumers may prefer HVs over other AFVs like gasoline, hybrid, PHEV, and BEV technologies. Carlucci et al. [79] explored the preferences for hybrid fuel technology and identified the Japanese market as having the world's highest market penetration of HVs. Sociopsychological public surveys were conducted by the New Energy and Industrial Technology Development Organization (NEDO) in 2008 and 2009, inquiring into people's perception toward the development of H_2 stations, knowledge of hydrogen fuel, awareness of fuel cell technology, and fuel-cell vehicles.

Itaoka et al. [80] investigated the difference in awareness through a survey in 2015 and compared the results with the two previous surveys conducted by the NEDO in 2008 and 2009. Investigations highlight the increase in the awareness level and reported a considerable improvement in knowledge on fuel-cell vehicles, hydrogen fuel infrastructure, and fuel cell technology. The survey results reported by the NEDO represent the views of the general public with no real-time experience of driving HFCVs. Risk perception studies highlight the importance of providing risk information related to the development of H_2 fuel infrastructure [81]. Further, Tanaka et al. [82] performed a comparative discrete choice analysis to estimate Japanese and US consumers' willingness to pay (WTP) for BEVs and PHEVs based on an SP survey conducted in 2012. Ito et al. [83] examined the potential demand for infrastructure investment in AFVs

based on Japanese consumers' WTP for this type of vehicle under various refueling scenarios. Deloitte conducted a comparative study in 2014 on a dataset from six countries to examine AFV preferences. The alternative powertrains in their research were HV/PHEV, BEV, and fuel cell electric vehicles (FCEVs). The report concluded that 26% of Japanese respondents preferred to be driving HVs in the next five years, while only 5% showed an interest in FCEV [84]. Kudoh and Motose [85] investigated Japanese consumers' preferences for BEVs by applying a conjoint analysis on a dataset collected by a questionnaire survey during 2009–10.

Investigations that gather information using empirical data can be more insightful in understanding consumers' demographic profile, attitudes, and perceptions. To the best of the authors' knowledge, no study has been undertaken to explore the socioeconomic profiles of Japanese consumers interested in buying HFCVs. Unlike Europe and the USA, the Japanese literature still lacks research on potential early adopters of HFCVs. Japanese literature on the adoption of AFVs has an abundance of studies that investigate consumers' preferences for BEVs, whereas few studies included HFCV in the stated preference hypothetical scenario and do not provide insight into the potential early adopters of HFCVs. This study examines the socioeconomic characteristics of potential HFCV early adopters and compares them with those of non-adopters. This is a significant research gap that needs to be explored, and this research attempts to investigate consumers' socioeconomic profiles using empirical data collected through a computer-assisted web interviewing (CAWI) survey.

Hypothesis development

The previous sections highlighted the existing empirical studies on different fuel technologies and theory concerning the relationship between socio-demographics and the adoption of new fuel technology. An important research question arises here, "who drives HFCVs and what are the differences in the socioeconomic characteristics of HFCV owners from others?" It forms the basis for the development of hypothesis for this study.

H_0: There exist no difference in the socio-economic attributes of the two groups with and without interest in HFCV.

Methodology

For this study, data was adopted from a CAWI survey conducted between August and November 2018 on 500 potential car buyers based in Aichi Prefecture, Japan. The prefecture is home to Japan's largest automotive manufacturer Toyota and has the highest number of passenger HFCV ownership as well as total vehicle ownerships in the country [86].

Thus, it is the most relevant location to explore consumers' socioeconomic status and perception of hydrogen fuel vehicles.

The survey sample was screened by asking a question about consumers' intention to buy a car in the next two years. Only those respondents who showed their intention to purchase a car were allowed to participate in the survey. The questionnaire survey included detailed information on socioeconomic characteristics, including age, household income, education level, household size, job status, information on current vehicle, frequency of traveling, everyday mobility in terms of purpose of trip, and future family car buying decision power. The second part of the survey comprised questions on fuel-cell vehicles, interest in segment size, and reasons for purchasing a car.

Researchers have also investigated life cycle composition as a socioeconomic feature of vehicle households by fuel type [87–89]. Fry et al. [90] examined age, socioeconomic status in lieu of household income, qualification, home ownership, number of vehicles, and knowledge of AFVs. Hardman [63] considered sex, age, highest level of education, household income, number of people in the household, and status of car ownership. In this study, consumers' demographic and socioeconomic factors include sex, age, level of education, household income, household size, number of vehicles in the household, description of currently owned cars, travel pattern, purpose of travel, knowledge on HFCVs, reasons for car purchase, interest in vehicle segment size, and fuel technology. Respondents in this questionnaire comprised a unique sample, as some of them had experience of both PHEV/HVs and BEVs, and thus provided a broad cross-section of the target population that could make rational choices in the experiment study.

This study executes statistical approaches and descriptive statistics to explore the similarities and differences between socioeconomic factors of potential early adopters of HFCVs and others. Recent studies relate consumers' interest in hydrogen vehicles with their zero tail-pipe emissions, potential for mass domestic production, fast refueling time, and high efficiency of fuel cells high efficiency [91–93].

The present questionnaire evaluated interest in HFCVs based on socioeconomic characteristics, knowledge, and awareness of HFCVs, experience in using other fuel technologies, and increase in hydrogen-related developments in a range of niche transportation sectors in Japan. In this study, potential early adopters of HFCVs represent a group of individuals who are interested in purchasing and using hydrogen-powered vehicles, which is a prerequisite for the intention to purchase. Main question presented in the questionnaire to capture respondent's interest in the vehicle fuel technologies was: What type of car you are interested in? (Translated from the actual question in Japanese). Respondents were allowed to choose multiple responses from the four different vehicle fuel technologies:

gasoline/diesel; PHEV/HV; BEV; HFCV. 6.4% (32 counts) of the respondents showed interest in HFCV while 21.1% (106 counts) in BEV, 58.2% (291 counts) in PHEV/HV and 69.4% (347 counts) in gasoline/diesel. In this study, the former 6.4% of the respondents who are interested in HFCV are treated as potential early adopters of HFCVs, and compared with the others (93.6% of the respondents). We also carried out the comparison analysis using the three groups: potential early adopters of HFCV, those who are interested in BEV but not in HFCV (15.4%, 77 counts), and the others (78.2%, 391 counts). The potential similarity between those who are interested in HFCV and those in BEV, and the potential difference between those who are interested in BEV and the others are considered in the three-groups analysis. As shown in the appendix, the results of the three-groups analysis on the characteristics of the potential early adopters of HFCV are almost the same as those of the two-groups analysis.

Through a t-test and Pearson chi-square (X^2) test, we examined the effect of socioeconomic characteristics on attitudes. The t-test compares the mean between two samples to examine whether a null hypothesis of the means being equal can be rejected and to what level of significance. We applied the t-test for socioeconomic variables that are continuous in nature, while the chi-square test determines the relationship between two categorical variables. The analysis aims to validate the relationship between the socioeconomic characteristics of the respondents, attitudes and discernments held about different fuel technologies, and their contextual environment.

Results

A comparison of the socioeconomic profiles of the potential early adopters of HFCVs and the rest is presented in Table 1. The table shows the household income, sex, age, level of education, number of people in the household, current number of vehicles, and work status. The sample found more female proportions of potential HFCV early adopters than others. Nearly, 47% of the respondents who showed their interest in buying HFCV in the next two years were female compared with 35% of the respondents with no interest in HFCVs who were female. This can correlate with previous studies on AFVs, concluding that more women are making the switch to cleaner fuel vehicles [94]. This aspect of female respondents is partially supported by previous studies, which have shown that women hold more pro-environmental and pro-sustainability values, can adapt to new technology faster, and prefer fuel-efficient cars [95–99]. In the sample in this study, 50% of the potential HFCV early adopters have an undergraduate degree, and 16% have higher graduate degrees. These respondents have high household incomes, 44% of the respondents who answered the income question had a household income of ¥ 11—16 million (US$ 105,000–150,000), and 3% earned more than

¥ 17 million (US$ 170,000) annually. This sample of HFCV adopters are mostly aged 25–34, 35–44, or 45–54. Sixty-eight percent of HFCV adopters were aged 25–54, and 9% were aged 65–74 years. Approximately 35% of these owned two vehicles and nearly 25% owned three or more vehicles. In general, HFCV adopters have a higher number of household cars, are mostly male, have higher incomes, and are highly educated. The sample therefore conforms to previous studies on the socioeconomic characteristics of AFV early adopters in the literature [94,100– 111].

In our dataset, 36% of the respondents represent females, and in line with the Statistics Bureau of Japan's database that highlights Aichi Prefecture under demographic structure where males outnumber females [112]. Average yearly household income in our dataset is JPY 4.80 million, which is comparable to the Japanese household income distribution map that shows JPY 5.04 million as an annual yearly household income for Aichi Prefecture [113]. According to the employment status survey conducted by the Statistics Bureau of Japan in 2017, 62.5% of the population was engaged in office work either as regular or irregular office staff, and in our dataset, percentage of respondents involved in such work is 62.6 that shows the consistency of the questionnaire survey [114]. Precisely, the demographic characteristics of the present survey on respondents in Aichi Prefecture do not exactly correspond to the rest of the population of Japan. The average household size in the investigation sample was 3.03, which is above the national average of 2.33 in 2015, as measured by the Statistics Bureau of Japan. Further, the average household owns 1.7 cars, which is in disparity with the statistics of JAMA [115], according to which, on average, a Japanese household owns 1.06 cars, down from 1.12 in 2006. This contrast is explicable, as car ownership mainly depends on the location of the household.

Around 98% of the respondents who don't have interests in HFCVs are unexperienced in driving battery electric vehicles compare to 90% of the potential HFCV respondents. Both the groups, Potential HFCV adopters and others have around equal access to company maintained parking while percentage of the HFCV adopters with access to parking attached to their home is more than others. Both groups, HFCV adopters and others travel frequently or sometimes with percentage ranging from 55 to 60, and cover around 100 km's weekly.

Table 1 Socioeconomic profile of sampled respondents

Characteristics		**HFCV adopters**		**Others**	
		n	%	n	%
Sex	Female	15	46.88	164	35.04

	Male	17	53.13	304	64.96
Age	17–24	3	9.38	17	3.63
	25–34	8	25.00	120	25.64
	35–44	6	18.75	121	25.85
	45–54	8	25.00	102	21.79
	55–64	4	12.50	75	16.03
	65–74	3	9.38	33	7.05
Household income	Less than ¥ 1 (M)	2	6.25	15	3.21
	¥ 1–2.99 (M)	1	3.13	35	7.48
	¥ 3–4.99 (M)	4	12.50	76	16.24
	¥ 5–6.99 (M)	6	18.75	107	22.86
	¥ 7–8.99 (M)	3	9.38	106	22.65
	¥ 9–10.99 (M)	1	3.13	39	8.33
	¥ 11–12.99 (M)	3	9.38	42	8.97
	¥ 13–14.99 (M)	6	18.75	20	4.27
	¥ 15–16.99 (M)	5	15.63	6	1.28
	¥ 17 (M) or more	1	3.13	22	4.70
Education level	Junior high school	1	3.13	7	1.50
	Senior high school	5	15.63	108	23.08
	Junior college	5	15.63	45	9.62
	Undergraduate degree	16	50.00	246	52.56
	Graduate degree	5	15.63	51	10.90
	Other professional degree	0	0.00	11	2.35
Household size	1	4	12.50	63	13.46
	2	4	12.50	111	23.72
	3	7	21.88	119	25.43
	4	12	37.50	124	26.50
	5	2	6.25	34	7.26
	6 or more	3	9.38	17	3.63
Number of household vehicles	0	4	12.50	14	2.99
	1	9	28.13	213	45.51
	2	11	34.38	173	36.97
	3	7	21.88	48	10.26

	4 or more	1	3.13	20	4.27
Work status	Company employee	17	53.13	296	63.25
	House husband / housewife	3	9.38	45	9.62
	Part-time job	5	15.63	49	10.47
	Self employed	4	12.50	24	5.13
	Student	2	6.25	11	2.35
	Unemployed	0	0.00	28	5.98
	Others	1	3.13	15	3.21
BEV experience	Experienced	3	9.38	7	1.49
	Un-experienced	29	90.62	461	98.5
Parking at office	Company parking	21	65.62	339	72.43
	Coin parking near office	6	18.75	49	10.47
	Others	1	3.12	19	4.05
	I don’t know	4	12.5	61	13.03
Parking at home	Home parking	27	84.38	326	69.65
	Apartment parking	3	9.38	108	23.07
	Monthly rental	1	3.12	31	6.62
	Others	1	3.12	3	0.64
Weekly distance travelled	0-99	14	43.75	236	50.42
	100-199	9	28.12	142	30.34
	200-299	5	15.62	54	11.53
	300-399	2	6.25	20	4.27
	400 km or more	2	6.25	16	3.42
Frequency of using expressways	Always	3	9.38	23	4.91
	Frequently	11	34.38	96	20.51
	Sometimes	8	25	160	34.18
	Occasionally	7	21.87	124	26.49
	Rarely	3	9.37	65	13.88

One of the research questions that this study investigated was, “Who intends to buy HFCVs and what are HFCV owners’ socioeconomic characteristics?” To gain an understanding of this, we compared the socioeconomic profile of potential HFCV adopters and non-adopters using t-tests and chi-square (X2) tests.

Table 2 shows results for the chi-square test comparing potential HFCV adopter and other's sex, education level, work status, and previous experience of driving PHEV/HVs and BEVs. The most significant difference was observed for previous experience in driving BEVs at 99% confidence interval (*p*-value <.01). The result of this analysis on previous BEVs experience shows that the null hypothesis (H0) of there being no difference in the means between two samples can be rejected. This difference is because a larger number of potential early adopters of HFCVs have more previous experience in driving BEVs than respondents without interests in HFCVs. This is in line with the previous studies on early adopters of fuel-cell vehicles by Hardman and Tal [65], in which ownership of previous BEVs was significantly different for HFCV households. There were no significant differences in the current ownership status of PHEV/HVs for between the two groups. The study found no difference between the expected and observed frequencies for sex, education level, employment status, PHEV/HVs experiences, and parking at home/office between the two groups. Both HFCV adopters and non-adopters are mostly male with higher level of education. Though, percentage of HFCV respondents possessing higher graduate degree was slightly higher than respondents without interest. Most of the respondents in the two groups were company employees with access to free company-maintained parking near offices. Unemployment rate for non-adopters in the study sample is 6% against HFCV adopters for which the unemployment rate is 0%.

Table 2 Pearson's chi-square results comparing differences between potential early adopters of HFCVs and others

Variable	N	df	Chi square	p-value
Sex	500	1	1.82	0.17
Education level	500	4	3.7	0.59
Work status	500	6	7.8	0.25
PHEV/HVs experience	500	1	0.18	0.67
BEV experience	500	1	10.79	<.01***
Parking at office	500	3	1.69	0.64

Parking at home	500	3	5.64	0.13
Distance travelled	500	4	1.67	0.79
Frequency of using expressway	500	4	5.28	0.27

Significance: *p<.1, **p<.05, ***p<.01

There were no significant differences in the frequency of using expressways and distance traveled between the two groups. Both HFCV adopters and non-adopters use their vehicles, frequently covering more than 200 km/week. Deloitte [84] established a profile of BEV early adopters for the years 2011–2020, which includes young individuals and higher-income households that have an average income of more than US$ 114,000 in an urban location, currently own one or more vehicles, are influenced predominantly by the reliability of vehicles, have the perception of electric vehicles being a greener technology, and drive an average of 100 miles per week. Previous studies on cleaner fuel vehicles and the adoption of new technologies also highlighted some of the characteristics of early adopters as being highly educated, younger in age, and from higher-income households. Considering the characteristics of early adopters highlighted in previous studies [116–118], we may assume that the sample in this study is distinctive, to some extent, to any other sample of automotive early adopters. This makes their impressions more purposeful and relevant, as these types of people are likely to adopt HFCVs.

Table 3 shows the results of the t-test comparing the means for household income, age, household size, and current vehicle status. The t-test results show the significant differences in household income. The mean income of the HFCV respondents was significantly different from the other respondents, suggesting that higher income earners perceive HFCVs differently from other AFVs in the market. In contrast, there was no significant difference in age, household size, and current vehicle ownership between the two groups. In the study on consumer attitudes toward fuel-cell vehicles post-trial in the UK, no significant difference in the means of the number of cars in a household and the number of people in a household were reported through a t-test result that compared BEV early adopters and fuel-cell vehicle trial participants. The t-test finding on age in this study demonstrates the variance in the literature on the age of HFCV early adopters [11,65]. Hardman and Tal [63] reported fuel-cell vehicles household as of slightly higher age than BEV households. Respondents in the fuel-cell vehicle trial study were of a younger age group than the BEV households in the fuel-cell vehicle trial study in the UK [11].

Table 3 - T-test results comparing the means of respondents' socioeconomic and current vehicle status

Variable		Vehicle type	N	Mean	Std Dev	t ratio	p-value
Socio-economic status	Household income	Non-HFCV	468	7,569,947	4,056,717	-2.20	0.03**
		HFCV	32	9,620,313	5,159,794		
	Age	Non-HFCV	468	43.72	12.91	0.57	0.56
		HFCV	32	42.25	13.96		
	Household size	Non-HFCV	468	3.01	1.28	-1.50	0.13
		HFCV	32	3.40	1.41		
Vehicle status	Number of vehicles	Non-HFCV	468	2.67	0.86	-0.41	0.68
		HFCV	32	2.75	1.04		
	Current vehicle price	Non-HFCV	468	2,567,357	1,744,300	-0.38	0.70
		HFCV	32	2,714,286	1,996,611		

Significance: *p<.1, **p<.05, ***p<.01

In the sample in this study, 26% of HFCV potential adopters currently own at least one AFV. Most HFCV potential adopters own one AFV, with 8% having two, and close to 1% having three AFVs (Fig. 3). The HFCV adopters own fewer AFVs than non-adopters, with nearly 29% being current AFV drivers. The t-test revealed that there were no differences in the current vehicle price for both groups.

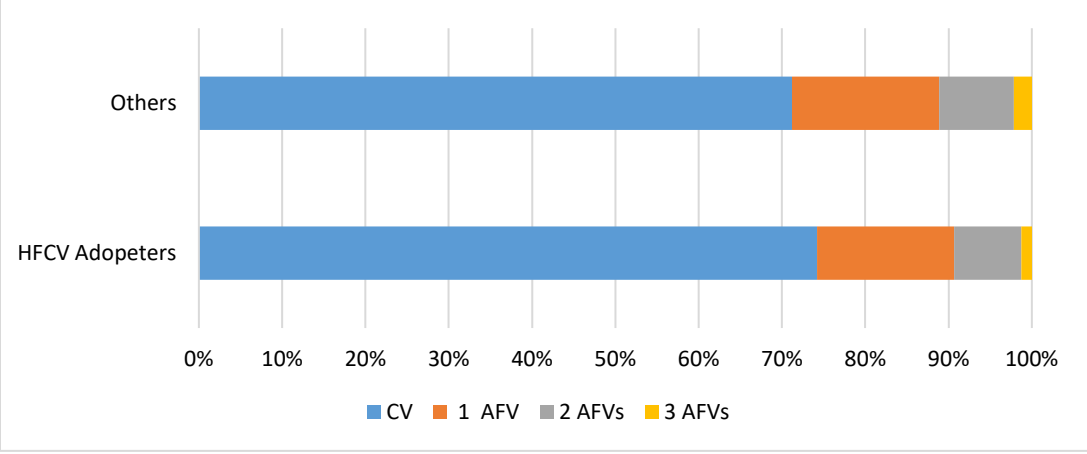

Fig. 3 Percentage of HFCV and others who currently own AFVs (PHEV/HVs, BEVs, HFCVs)

In an attempt to gain more practical and theoretical insights, participants were asked to respond to the questions, "what is the reason of the car purchase?"; "what type of information do you have about Hydrogen Fuel Vehicles?" in the second part of the questionnaire. The purpose for the second part was to understand any benefits of the vehicles that the previous question may have overlooked. Table 4 shows a summary of the responses on reasons for car purchase and knowledge of HFCVs for both groups.

Table 4 Sample distribution on reasons for car purchase and knowledge on HFCVs*

Characteristics	Category	HFCV Adopters		Others	
		n	%	n	%
Reasons for car purchase	Interest in replacing current vehicle	18	56.25	220	47.01
	Current vehicle getting old	15	46.88	259	55.34
	Intention to adopt new fuel technology	10	31.25	45	9.62
	Interest in vehicle with good mileage	15	46.88	63	13.46
	Interest in vehicle with zero carbon emissions	6	18.75	6	1.28
Knowledge of hydrogen vehicles	Hydrogen as an alternative fuel technology	22	68.75	191	40.81
	Hydrogen vehicle purchase price	18	56.25	125	26.71
	Driving range	21	65.63	138	29.49
	Governmental incentives on HFCV purchase	20	62.50	122	26.07
	Hydrogen refueling stations	21	65.63	197	42.09
	I have no information	6	18.75	153	32.69

* Multiple answers are allowed.

In Table 5, the results demonstrate a significant difference between the two groups in the variables for interest in vehicles with zero carbon emissions, intention to adopt new fuel technology, and vehicle with good mileage at 99% confidence interval. This shows that more HFCV respondents are interested in buying a new technology vehicle with good mileage and zero carbon emissions compared to respondents interested in other vehicles. This behavior might

have been triggered by disruptive technology-driven trends in the market, seeking comfort and purchase benefits on new green fuel technologies, or governmental incentives and promotion efforts for hydrogen vehicles in Japan.

Table 5 Pearson's chi-square results comparing differences between potential early adopters of HFCVs and others: Reasons for a car purchase

Variable	N	df	Chi square	*p*-value
Interest in replacing current vehicle	500	1	0.68	0.41
Current vehicle getting old	500	1	0.56	0.45
Intention to adopt new fuel technology	500	1	12.20	<.01***
Shift to vehicle with good mileage	500	1	22.92	<.01***
Interest in vehicle with zero carbon emissions	500	1	31.92	<.01***

Significance: *p<.1, **p<.05, ***p<.01

Respondents were also asked about the type of information and knowledge on HFCVs. The chi-square test was used to compare knowledge related to fuel-cell vehicles. Table 6 shows that knowledge on each information topic was significantly different between the two groups. The potential early adopters of HFCV had more information on hydrogen fuel technology, price of fuel-cell vehicle, driving range, purchase incentives, and refueling stations. One of the interesting findings from this question is that the findings conform to the current efforts by the Japanese private and government sectors to expand the awareness of hydrogen fuel vehicles and hydrogen refueling networks across the country to meet the revised targets set in the Strategic Roadmap for Hydrogen and Fuel Cells [1]. Currently, Japan has the largest number of HRSs in the world, and the target is to construct 320 stations by 2025 [6].

Table 6 Pearson's chi-square results comparing differences between potential early adopters of HFCVs and others: Knowledge on HFCVs

Variable	N	df	Chi square	*p*-value
Hydrogen as an alternative fuel technology	500	1	9.6	<.01***
HFCV price	500	1	12.80	<.01***
Driving range	500	1	18.04	<.01***
Purchase incentives	500	1	19.55	<.01***
Refueling stations	500	1	6.74	<.01***
No information	500	1	2.68	0.1*

Significance: *p<.1, **p<.05, ***p<.01

Discussion & Conclusion

This study focuses on the identification of sociodemographic attributes that may contribute to HFCV ownership. The study includes a two-step method to investigate sociodemographic profiles of potential early adopters of HFCV: first, t-test and chi-square test to understand the similarities and differences in the means between the two groups. To the best of the authors' knowledge, this is the first study that focuses solely on the sociodemographic profiles of potential HFCV early adopters in Japan. There is some interesting empirical understanding that emanates from the analysis of the survey data of potential early adopters of HFCVs in Aichi Prefecture, which has the highest ownership of passenger HFCVs as well as total vehicle ownership among all prefectures in Japan, and a sample size of 500 respondents enabled the study to focus on socioeconomic variables.

The study found some differences in the respondents from each group that may explain why these consumers chose to adopt HFCV as a potential vehicle. There is a significant difference in the number of potential HFCV early adopters with the previous BEV experiences. Innovation research shows that BEV early adopters tend to enjoy a higher socioeconomic status due to their higher education level, income, and knowledge, which may positively impact the adoption of new products [119–122]. Another important determinant influencing the consumers' intention to adopt BEVs is driving range [123–126]. The study also found a significant difference (p<.01) in the number of HFCV

potential early adopters responding to the question about reasons to purchase a car. In the chi-square test results, the intention to adopt new technology, seeking a car with a longer mileage, and interest in zero-emissions vehicles were some of the emergent topics. HFCVs have both range and fueling-time advantages over other alternative zero-emission vehicles. In earlier studies, HFCV early adopters were also seen to give more weight to local air pollution and GHG emissions [65,127]. The significant difference in income (95% confidence interval) between the two groups conforms to the findings of previous studies that highlight higher income levels of HFCV potential adopters and early adopters [11,24,63–65,128,129].

This study found no statistical significance in the education levels of respondents in each group. In contrast, previous studies highlight the positive impact of education on the adoption of environmentally friendly vehicles. The results of previous studies reveal that the level of education significantly impacts the preferences for HFCVs among early and potential adopters [9,24,63–65,68,72,127,130–133]. Hackbarth and Madlener [42] found no significant impact of higher education level on the adoption of hydrogen vehicles. The findings of studies on the influence of demographic variables are quite diverse and sometimes even contradictory.

The significant differences between the two groups in terms of knowledge of hydrogen fuel-cell vehicles provided an interesting insight into the HFCV potential early adopters. The results show that respondents with interests in HFCVs may have greater knowledge of HFCVs. This information corresponds to the fact that a higher level of knowledge about the technology can lead to a greater diffusion of hydrogen vehicles in the consumer market. Some of the earlier studies considered the lack of knowledge and information on HFCVs as one of the barriers to the successful diffusion of these vehicles [13,127,130]. At this stage, we can conclude that a greater level of knowledge and information on HFCVs could play an important role in the diffusion process, although the impact of knowledge on adoption is complicated. Consumers who already have an interest in hydrogen-related technologies can seek knowledge and information on HFCVs. Therefore, the assumption of the positive relationship between adoption and the level of knowledge is not always true.

Unlike in the US, Germany, China, Norway, and other major markets, BEVs are not as popular in Japan. As of 2019, the share of BEVs was roughly estimated at approximately 0.9%, which was 0.2% lower than that from the previous year. This puts BEVs in the list of technology currently with an immature market in Japan. In contrast, the Government of Japan is poised for the widespread adoption of HFCVs, in the wake of the country's goal to realize a hydrogen-based personal and commercial transportation system. The difference in the purchase price and technology

advancement of HFCVs in comparison with other available vehicular technologies, i.e., PHEV/HVs, BEVs, and CVs, place the consumers with interest in HFCVs in a separate group and the socioeconomic characteristics of these respondents require further insight. A novel and original contribution of this study is an insight into the socioeconomic characteristics of the HFCV potential early adopters in Japan. The findings of this research reveal that HFCV potential early adopters are higher-income earners with previous experience in BEVs, are interested in the adoption of new technology and ZEVs, and have greater knowledge on HFCVs and related technologies. On the other hand, the study found no significant difference in the number of household vehicles, household size, travel patterns, and age between each group. However, in some previous studies, factors including household size, age, and number of household vehicles were highlighted as influencing factors in the adoption of AFVs. Consumers' interest and attitudes differ across the different geographic markets and largely depend on prevailing social and cultural norms. This study is unique in that it precisely highlights the prevailing socioeconomic characteristics of the respondents with interests in HFCVs to a limited extent. Additionally, the sample in this study outlines the demographics of the population in Aichi prefecture only, which is home to Toyota and cars remain in higher demand in this prefecture. Therefore, the results cannot be generalized to the Japanese population because the sample is not representative of the entire population Japan.

Policy implications

Currently, income significantly distinguishes the user groups between HFCV and other vehicle consumers. The current price tag of HFCVs makes it difficult for other vehicle consumers to shift to this technology. The PHEV/HVs purchase price lays the foundation for policymakers to adjust the current price tag to the level at which it is agreeable to the average consumer's social and economic behavior in line with personal preferences. The price difference of ¥ 3 million between HFCV and HV is the major bottleneck to the successful diffusion of these zero-emission vehicles. In the revised road map for hydrogen and fuel cells, the Government aims to achieve a cost reduction of HFCV to the level of hybrid vehicles by reducing the difference to ¥.7 million by 2025. The knowledge level of consumers about HFCVs and related technologies and environmental attitudes may impact acceptance positively. Japan is already leading the world in fuel-cell infrastructure development and green hydrogen production. Knowledge on incentives, refueling time, infrastructure development, reduction in purchase price, and awareness of hydrogen related technologies can increase sales. The Government is incentivizing the hydrogen sector to achieve the targets of 200,000 HFCVs by 2025 and 320 HRSs by 2025, and has devised a plan to reduce the cost of hydrogen station development from ¥ 350 million

to ¥ 200 million, and operation cost from ¥ 34 million to 15 million per year, respectively. Earlier studies also highlighted purchase price and lack of hydrogen refueling infrastructure as the major barriers to the widespread adoption of HFCVs [9,93,135–138].

The socioeconomic characteristics of potential early adopters in this study conform to the characteristics of early adopters by Rogers [66]. Early adopters are highly educated, have higher incomes and greater concerns for GHGs, and are interested in shifting to a new technology. Considering the attributes of these consumers, which are generally different from other respondents in the society, policymakers have to conceptualize the diffusion policies to attract early adopters for successful diffusion. The proportion of respondents who have not shown their interest in HFCVs confirm that these respondents intentionally rejected HFCVs. The confirmed low levels of knowledge about HFCVs are likely responsible for the low level of interest in HFCVs (intentional rejection).

Figure 4 depicts the sharp sales decline of HFCVs since April 2020 in the wake of a coronavirus outbreak that dented consumers' sentiments and resulted in sluggish sales in comparison to the previous year. A nation of approximately 127 million persons, Japan has, for now, managed to contain the spread of COVID-19, with economic activities revitalizing and restrictions being eased in different parts of the country. To keep the hydrogen society goal alive amid growing fears over COVID-19, the Tokyo Olympics provides a chance to relocate Japan's efforts to preserve the environment by using hydrogen as a fuel in the transportation sector. Despite the sharp plunge in HFCV sales and slowdown in hydrogen-society developments due to the global pandemic, efforts continue toward a path of making Japan the world's first hydrogen-fueled society. In the post-COVID environment, HFCV sales are expected to resurge as Japanese automakers and investors continue to invest in hydrogen infrastructure and related technologies that can trigger the consumers' desire to shift to hydrogen vehicles. The rescheduled Tokyo Olympics will be a perfect opportunity for advocates of a hydrogen economy to demonstrate to the world the Japanese efforts and developments related to hydrogen energy, with plans for deployment of hydrogen fuel-cell buses, hydrogen re-fueling stations, and hydrogen fuel-cell vehicles near the Olympics arena.

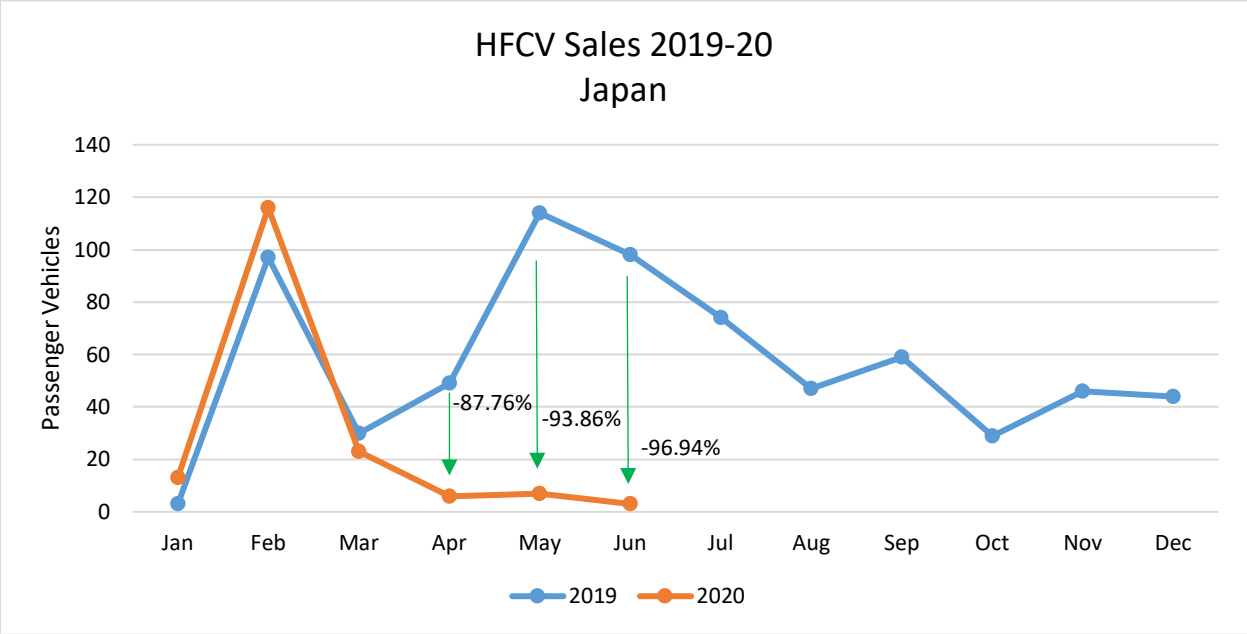

Fig. 4 Hydrogen fuel-cell vehicles yearly sales comparison

Limitations

This study has a shortcoming that might have impacted the results unequivocally. In a bid to explore the profile of potential early adopters of HFCVs, the questionnaire in this study focused only on the potential car buyers based in Aichi Prefecture. To address the shortcomings of the current study, a future study could include larger data from HFCV owners based in Aichi Prefecture, Fukuoka Prefecture, and the Greater Tokyo Area. Hydrogen projects in Tokyo and Fukuoka Prefecture, represents Japan's progress and leadership in the path toward a hydrogen society. In the next questionnaire survey, questions related to the decision to adopt HFCV, important factors in the decision to purchase HFCV, experience with the vehicle so far, car lease options, and questions on the performance and fuel availability in comparison with other vehicle technologies may assist policymakers, automakers, and Japan H2 Mobility-a company for the development of hydrogen stations understand the HFCV drivers' perspective and how to overcome the adoption barrier, if any.

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Appendix

The results of the three groups comparison are show below. The potential early adopters of HFCV is 6.4% (32 counts) of the respondents who showed interest in HFCVs, while the potential BEV adopters are those who are interested in BEV but not in HFCV (15.4%, 77 counts), and the others are those who are interested in neither HFCV nor BEV (78.2%, 391 counts).

Table A1 Pearson's chi-square results comparing difference among three groups

Variables	BEV adopters - Others				HFCV adopters - Others				HFCV adopters - BEV adopters			
	N	df	Chi-square	p-value	N	df	Chi-square	p-value	N	df	Chi-square	p-value
Sex	468	1	1.1	0.29	423	1	2.15	0.14	109	1	0.41	0.52
Education level	468	4	4.58	0.47	423	4	4.59	0.47	109	4	1.69	0.89
Work status	468	6	1.69	0.89	423	6	8.01	0.24	109	6	6.14	0.41
PHEV/HVs experience	468	1	1.91	0.17	423	1	0.42	0.52	109	1	0.06	0.81
BEVs experience	468	1	0.09	0.76	423	1	2.82	0.09*	109	1	2.07	0.15
Parking at office	468	3	2.07	0.56	423	3	1.38	0.71	109	3	2.78	0.42
Parking at home	468	3	1.95	0.58	423	3	5.62	0.13	109	3	4.93	0.18
Distance travelled	468	4	5.41	0.24	423	4	3.05	0.55	109	4	6.5	0.16
Frequency of using expressways	468	4	8.8	0.07*	423	4	5.01	0.28	109	4	7.03	0.13

Significance: *p<.1, **p<.05, ***p<.01

Table A2 T-test results comparing the mean of respondent's socio-economic status and current vehicle status

Variable	Vehicle type	N	Mean	Std Dev	t-ratio	p-value
Household income	Others	391	7,494,079	3,923,189	-0.35	0.72
	BEV	77	7,670,909	4,047,550		

		Others	391	7,494,079	3,923,189	-2.27	0.02**
		HFCV	32	9,620,313	5,159,794		
		BEV	77	7,670,909	4,047,550	-1.89	0.06**
		HFCV	32	9,620,909	5,159,794		
	Age	Others	391	43.93	13.05	0.84	0.4
		BEV	77	42.64	12.23		
		Others	391	43.93	13.05	0.66	0.51
		HFCV	32	42.25	13.96		
Socio-economic status		BEV	77	42.64	12.23	0.14	0.89
		HFCV	32	42.25	13.96		
	Household size	Others	391	2.99	1.27	-0.55	0.58
		BEV	77	3.09	1.37		
		Others	391	2.99	1.27	-1.59	0.12
		HFCV	32	3.41	1.41		
		BEV	77	3.09	1.37	-1.07	0.28
		HFCV	32	3.41	1.41		
Vehicle status	Current vehicle price	Others	391	2,506,429	1,580,532	-1.27	0.2
		BEV	77	2,870,395	2,389,228		
		Others	391	2,506,429	1,580,532	-0.54	0.59
		HFCV	32	2,714,286	1,996,611		
		BEV	77	2,870,395	2,389,228	-0.33	0.74
		HFCV	32	2,714,286	1,996,611		
	Number of vehicles	Others	391	2.69	0.90	1.21	0.23
		BEV	77	2.58	0.66		
		Others	391	2.69	0.90	-0.31	0.76
		HFCV	32	2.75	1.04		
		BEV	77	2.58	0.66	-1.27	0.41
		HFCV	32	2.75	1.04		

Significance: *p<.1, **p<.05, ***p<.01

Table A3 Sample distribution on reasons for car purchase and knowledge on HFCVs

Category	Characteristics	HFCV adopters		BEV adopters		Others	
		n	%	n	%	n	%
Reasons for car purchase	Interest in replacing current vehicle	18	56.25	40	16.62	180	46.04
	Current vehicle getting old	15	46.88	40	16.62	219	56.01
	Intention to adopt new fuel technology	10	31.25	14	5.82	31	7.93
	Interest in vehicle with good mileage	15	46.88	21	8.73	42	10.74
	Interest in vehicle with zero carbon emissions	6	18.75	2	0.83	4	1.02

Knowledge on HFCVs	Hydrogen as an alternative fuel technology	22	68.75	32	41.56	159	40.66
	Hydrogen vehicle purchase price	18	56.25	25	32.47	100	25.58
	Driving range	21	65.63	28	36.36	110	28.13
	Governmental incentives	20	65.5	29	37.66	93	23.79
	Refueling stations	21	65.63	42	54.55	155	39.64
	No information	6	18.75	18	23.38	135	34.53

Significance: *p<.1, **p<.05, ***p<.01

Table A4 Pearson's chi-square results comparing difference among three groups: Reasons for car purchase

Variable	Group pair	N	df	Chi-square	p-value
Interest in replacing current vehicle	BEV - Others	468	1	0.9	0.34
	HFCV - Others	423	1	1.23	0.26
	HFCV - BEV	109	1	0.17	0.68
Current vehicle getting old	BEV - Others	468	1	0.43	0.51
	HFCV - Others	423	1	0.99	0.32
	HFCV - BEV	109	1	0.23	0.63
Intention to adopt new fuel technology	BEV - Others	468	1	7.78	p<.01***
	HFCV - Others	423	1	18.38	p<.01***
	HFCV - BEV	109	1	2.25	0.13
Shift to vehicle with good mileage	BEV - Others	468	1	15.09	p<.01***
	HFCV - Others	423	1	33.12	p<.01***
	HFCV - BEV	109	1	3.93	.04**
Interest in vehicle with zero emissions	BEV - Others	468	1	1.26	0.26
	HFCV - Others	423	1	40.27	p<.01***
	HFCV - BEV	109	1	8.67	p<.01***

Significance: *p<.1, **p<.05, ***p<.01

Table A5 Pearson's chi-square results comparing difference among three groups: Knowledge on HFCVs

Variable	Group pair	N	df	Chi-square	p-value
Hydrogen as an alternative fuel technology	BEV - Others	468	1	0.02	0.88
	HFCV - Others	423	1	9.53	p<.01***
HFCV price	HFCV - BEV	109	1	6.68	p<.01***
	BEV - Others	468	1	1.56	0.21
	HFCV - Others	423	1	13.84	p<.01***
Driving range	HFCV - BEV	109	1	5.35	.02**
	BEV - Others	468	1	2.09	0.15
	HFCV - Others	423	1	19.45	p<.01***
Purchase incentives	HFCV - BEV	109	1	7.82	p<.01***
	BEV - Others	468	1	6.43	.011**
	HFCV - Others	423	1	22.65	p<.01***
Refueling stations	HFCV - BEV	109	1	5.63	.017**
	BEV - Others	468	1	5.86	.0015**
	HFCV - Others	423	1	8.22	p<.01***
No information	HFCV - BEV	109	1	1.14	0.28
	BEV - Others	468	1	3.63	.05*
	HFCV - Others	423	1	3.31	.06*
	HFCV - BEV	109	1	0.28	0.59

Significance: *p<.1, **p<.05, ***p<.01