Public preferences for the use of Alternative Fuel Vehicles – a literature review

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Public preferences for the use of Alternative Fuel Hydrogen Vehicles – a literature review

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1. Introduction

The escalating environmental issues from the transportation sector has led to a number of possible regulations across the European Union, including the use of alternate fuels. The adoption of energy-sustainable transport innovations is crucial for climate change, and with appropriate strategies the dependency on fossil fuels can be reduced significantly. To address issues like diminishing energy resources and energy security challenges, the European Commission intends to reduce 60% of transport related CO_2 emissions by 2050 (Hoen and Koetse, 2014) and replace 10% of conventional fuels with biofuels, hydrogen and ecologically sourced electricity by 2020 (Fúnez Guerra et al., 2016).

The conventional fuel spikes receive a more swift energy policy response to insulate the economy rather than any Alternative Fuel Vehicles (AFV's), triggering the urgency among policy makers to recognize the need for alternative future energy options such as hydrogen. These backstop technologies offer energy security against supply side shocks because they are free from market volatility (Ambrose et al., 2017). However, policy makers are not interested in reducing energy consumption but rather to meet the demand by sourcing from renewable and sustainable alternatives (Ambrose et al., 2017).

Among many resources available, Hydrogen being simple and the most abundant chemical element in existence (Southall and Khare, 2016) can be used for various purposes, including transportation. Hydrogen as an energy vector can increase penetration of renewable and intermittent sources in the energy supply of the islands, allowing 100% renewable energy supply of island communities (Krajačić et al., 2008). Numerous studies have been conducted to try to understand the working efficiency of hydrogen as a technology innovation and as fuel cell for transportation. Hydrogen offers a wide range of benefits as it is a clean energy carrier and is thus receiving ever-greater attention as a policy priority (Ball and Wietschel, 2009). Hydrogen can contribute to the diversification of automotive fuel sources and supplies and offers the long-term possibility of being solely produced from renewable energies (Ball and Wietschel, 2009).

Environmental, economic and social concerns about the performance of the energy sector show the need for a transition towards a sustainable energy system (Iribarren et al., 2016). Public and private support is however essential for successful transition to a sustainable energy system (Al-Amin et al., 2016). The transition of hydrogen into energy systems is desirable for the achievement of long-term climate policy objectives (Yetano Roche et al., 2010).

Islands may play a prominent role in global development by becoming ideal locations for demonstration of new clean technologies and new pathways for sustainable development (Krajačić et al., 2008). Moreover, the Europeans Commission's recent White Paper on transport and the ambitious emission reduction targets, formulated with a time horizon up to 2050 makes islands ideal for demonstration. These communities have also attracted major attention with several European and national programs addressing sustainable development solutions by renewable energy technologies (Matera et al., 2009).

A significant portion of approximately 140 developing countries in the world are island communities, and every island community has its own economic, political, geographic and environmental characteristics that set them apart from the larger developing countries (Alves et al., 2000). These communities play an important role in the adoption process of any emerging technologies: supporting pre-commercial deployment, building public acceptance, and promoting innovation clusters, all of which lay the foundations for more widespread and sustained technology deployment (Shaw and Mazzucchelli, 2010). Island communities are susceptible to challenges like, insufficient critical mass, dispersed settlements, poor accessibility, vulnerability to climate change effects and limited networking opportunities (GREBE, 2017).

The majority of the European Islands suffer from large dependence on imported energy increasing economic pressures due to rising transport costs (Eleanor Denny, 2012). Remoteness and size of the communities' lead to small isolated markets with few actors and a low diversity of technologies (Marrero and Ramos-Real, 2010) pressuring the energy system intensively. Renewable energy technologies provide solutions for a more sustainable and self-sufficient energy supply, but the possibilities to balance fluctuations in power generation and demand through interregional electricity transmission are typically very limited or not available at all in island systems (Gils and Simon, 2017).

The Canary Islands [the Canaries] are a volcanic archipelago consisting of seven major islands and a few small isles and islets. They are located in the eastern Atlantic Ocean, between 27°37' and 29°25' North, and 13°20' and 18°10' West, in front of the Saharan coast of Africa. Along a length of 400 km from East to

West, the islands are Lanzarote, Fuerteventura, Gran Canaria, Tenerife, La Gomera, La Palma and El Hierro (Custodio and del Carmen Cabrera 2012). Island economies often rely on tourism, they account for approximately 50% of the GDP of the Canary Islands, a leading European destination receiving more than 13 million tourists a year (Askjellerud 2003).

Tenerife with a population of 0.89 million people is the main economic sector with annual visitors of 6.18 million in 2017 (Statista 2018) and guest-nights increasing from 11 million in 2010 to 14 million in 2014 (Gils and Simon 2017). The Teide National Park, a World Heritage Site, located on the island of Tenerife attracts more than 5 million tourist's visits annually. Being considered of outstanding natural value, the Teide stratovolcano, Tenerife's highest mountain and the world's third tallest volcano is a popular tourist destination attracts more tourists creating more pressure.

A study by González, Marrero et al. (2018), show that, in 2015 70% of the visitors travelled to the park by car, mostly rental cars, 28% by tour bus and only 2% by the public bus services. This high volume of traffic [2,400 cars per day] runs along a single road some 20 km long with 700 parking spaces for cars distributed in 22 car parks. Therefore, at peak hours the number of vehicles exceeds the load capacity of the park, causing a wide range of negative externalities for the environment such as high noise levels in certain areas, congestion, crowding in car parks.

Kovačić (2016) states the development of transport and growth of tourism strongly influences each other. Tenerife is the ideal site for the demonstration and development of hydrogen vehicles as tourism is ever increasing thus creating additional pressure on the energy system and creating high impact on structure and variability of the energy demand (Gils and Simon, 2017). Additionally, creating acute energy security challenges, higher delivery costs for their fuel, developing a quantitative imbalance between supply and demand (Askjellerud 2003).

The Hydrogen economy is one of the most fundamental approaches in building a sustainable supply and demand system (Gim et al., 2012). To meet this substantial energy demand, energy security and economic growth, the supply, infrastructure and fuel availability should be addressed. One of the options to balance this quantitative imbalance would be Logistics management using hydrogen as a fuel. Logistic management in the car rental business involves short-term decisions about the transportation, deployment of cars with regard to optimizing fleet utilization and maintaining a high service level [Fink

2016]. A number of technological innovations exists to support this logistic management. One such case would be the usage of hybrid vehicles, as hydrogen can offer a better solution for mobility via fuel cell electric vehicles without any emissions (Wulf et al., 2018).

At present, lack of hydrogen infrastructure (Kim et al., 2008), the lack of widespread service stations network and its associated externalities like the existing fueling infrastructure for gasoline and diesel, deter consumers from switching to new technologies referred as ‘‘excess inertia’’ (Achtnicht et al., 2012). These issues frame the competitive challenge in using hydrogen, as there exists a dilemma between centralized and the decentralized production, and a storage-and-delivery infrastructure (Kim et al., 2008). This could be addressed by bulk hydrogen storage providing the strategic energy reserve to guarantee national and global energy security in a world relying increasingly on renewable energy (Andrews and Shabani, 2012).

A number of existing studies show the diffusion of energy-sustainable transport innovation of hydrogen as fuels. For instance, Mourato et al. (2004) studies the use of hydrogen fuel taxis in London, another study in Stockholm conducted by Saxe [2006] shows the use of hydrogen in fuel cell buses. Similarly, there exists varieties of studies carried across globe, which pins the technological development and innovation of hydrogen usage for transportation. The transition of hydrogen into energy systems is considered by some to be desirable for the achievement of long-term climate policy objectives (Yetano Roche et al., 2010). Public as well as private support is however essential for such successful transition to a sustainable energy system (Al-Amin et al., 2016).

Work package 7 on the SEAFUEL project aims to estimate consumer preferences for the rental of hybrid cars on the largest Canary Island - Tenerife. The focus is on introducing green tourism i.e., to use hydrogen as an extended fuel for hybrid vehicles to power the local public transport fleets and tourist rental vehicles. This not only supports the shift towards a low-carbon economy but will also encourage more fuel-efficient transport and help facilitate the European Commission’s goal to increase the proportion of hydrogen vehicles to 25% of all vehicles in the European market by 2030 and 35% by 2040 (Southall and Khare, 2016, Tarigan and Bayer, 2012).

The following literature review provides an overview of EU policies in relation to hydrogen and transport, a background on the literature relating to ALF’s and the factors affecting the demand for ALF’s in different countries. Furthermore, a list of important attributes relating to public preferences for alternative fuel vehicles is outlined.

2. **Literature Review**

Despite the 1937 Hindenburg disaster (O'Garra 2005 and Schulte, 2004) studies on perceptions and attitudes of Hydrogen as an alternative vehicle fuel are gaining increasing attention, potentially because of its positive effects on the environment (Schulte, 2004). Much of the debate over the decade that has engaged hydrogen supporters, sceptics and opponents in terms of techno-economic challenges and opportunities of hydrogen energy include risk assessment and public perception influencing acceptance (Ricci et al., 2007). Hydrogen is widely recognized as an environmentally friendly energy carrier which can be generated from a variety of primary energy sources. It is suitable for a wide range of mass market applications including transport, portable, and stationary uses (Đukić et al. 2016).

The phrase 'Hydrogen Economy' dates back to 1970 when concerns about running out of oil, natural gas, and ultimately coal – for the exponential growth in global primary energy use, and the associated rising pollution levels, were first being raised (Andrews and Shabani, 2012). The hydrogen economy comprises the production of molecular hydrogen using coal, natural gas, nuclear energy, or renewable energy such as biomass, wind, solar; the transportation and storage of hydrogen in some fashion; and the end use of hydrogen in fuel cells (Kim et al., 2008). Today, among many alternatives, hydrogen emerges as a potentially clean energy carrier with a high specific energy content conditioned by the use of green sources and methods for hydrogen production (Iribarren et al., 2016).

Hanley et al. (2018) states that annually 50 million metric tons of hydrogen is produced globally, with the main use being a feedstock for ammonia production with 35% being used for oil refining. The flexibility of hydrogen as an energy carrier may have future applications in power to gas generation and electricity generation (Hanley et al. 2018), passenger and freight transport [fuel cell vehicles, internal combustion engines], thermal [solid oxide fuel cells, natural gas blending] and storage [liquid and gaseous hydrogen]

(Niaz et al. 2015). Hydrogen and fuel cells could reduce carbon dioxide emissions by a further 5% [1.4 Gt/year] by 2050 compared to just deploying efficiency measures [such as petrol-electric hybrid vehicles] and alternative fuels like ethanol (Andrews and Shabani, 2012).

The efficiency of the fuel cell system for passenger cars is around 40% compared to 25-30% for the gasoline/diesel powered internal combustion engine under real driving conditions (Ball and Wietschel, 2009). A study conducted using H2RES and HOMER software in island of Lastovo shows how transport and electricity needs can be accommodated through integration of energy flows. The results show 25% and 50% penetration of Electric Vehicles reduces energy consumption to 9.89tj and 7.85tj from 12tj (Pfeifer et al., 2015). Another study conducted using the accounting framework Mesap-PlaNet and REMix on the Canary Islands showed that locally available technology potentials are sufficient for renewable supply of the islands' power, heat, and land transport energy demands. The results highlighted the importance of power transmission in RE supply systems with 15% lower Supply costs (Gils and Simon, 2017).

Another study by Kai et al. (2007) at Yakushima Islands showed that hydroelectric power produced by electrolysis is sufficient to cover all the energy demands on this island and the total energy efficiency of the compressed hydrogen by the total electrical energy input to the station, was 25% of Low Heating Value and 30% of High Heating Value. Krajačić et al. (2008) showed when hydrogen was introduced as an energy vector for 4–6% of total yearly electricity demand, it was possible to satisfy 100% of transport load by hydrogen from renewable energy sources in the Island of Mljet - Croatia, Porto Santo - Madeira, Terceira - Azores, and Malta.

2.1 Consumer attitudes to hydrogen vehicles

The following literature outlines some of the key findings on consumer attitudes towards AFV's across various countries:

1. Mourato et al. (2004) utilized a contingent valuation method to reveal that driving hydrogen-fueled vehicles does not seem to raise safety concerns amongst taxi drivers.
2. Schulte (2004) states prior experience is a key factor by which public attitudes can be changed. Therefore, a combination of product exposure, formal education and marketing should be implemented in order to improve the understanding of hydrogen fuel and its benefits.

3. Haraldsson et al. (2006) states people are generally positive towards fuel cell buses and feel safe with the technology, drivers are also positive towards fuel cell bus projects. The environment was rated as an important factor. Sixty four percent of the bus passengers were not willing to pay a higher fee if more fuel cell buses were to be used and passengers over the age of 40 desired more information about fuel cells and hydrogen.
4. Ricci et al. (2007) stated that the public is concerned about the following topics; understanding hydrogen as an energy carrier, use of fuel in their daily lives, whether it would deliver the promise of realizing a better future, whether it would disrupt people's lifestyles and require a significant change in collective and individual behavior, how the economic and social costs would be distributed, and to whom any tangible benefits would accrue. Zimmer (2003) states the need to understand the idea of trust in the provision of information about hydrogen.
5. Ricci et al. (2008) focused on safety concerns, the need of more information, prior knowledge of hydrogen and environmental attitudes, direct experience of hydrogen buses, cost and convenience. According to their study, gender and age differences also were significant. Men appeared to have stronger beliefs than women, both positive and negative. Positive beliefs tended to be associated with younger groups and high education level.
6. Huijts and van Wee (2015) analysis indicates that those living nearer to a fueling station have more negative evaluation because they have a lower level of trust in the industry. Therefore, placing and maintaining a safe hydrogen fuel station may have a positive affect towards locals.
7. Southall and Khare (2016) states the number of respondents who, despite having been informed of the environmental benefits of RES hydrogen in the survey still went on to state they would like to see a reduction in pricing over conventional fuels. This would suggest that factors like cost is influencing the respondents' decision over fuel pricing over and above concern for the environment.
8. Ko et al. (2016) states technological development of alternative fuel vehicles like hydrogen fuel exists for a long time, but the deployment of AFVs still remains at the initial stage mainly because of the lack of refueling facilities. The deployment depends on AFV type, re-fueling facility type, demand estimation, location problem optimization and spatial coverage. Ko et al., also suggests focusing on traffic congestion as congestion incurs more fuel consumption and unreliable travel times.
9. Hoen and Koetse (2014) reviewed the literature on AFV preferences and found overall that next to purchase price and operating costs, driving range, recharge time and fuel availability may have

substantial effects on consumer preferences for AFVs. The authors also noted that emission reduction is also signaled as an important factor. Additionally, car type which includes the conventional technology, the hybrid, plug-in hybrid, fuel cell, electric and flexi-fuel car, the seven attributes that is, catalogue price, monthly costs, driving range, recharge/refueling time, additional detour time to reach a fuel or recharge station, number of available models, and policy measure were all found to be important.

2.2 Acceptance and the adopters

Hydrogen acceptance, in its broader meaning, includes issues related to the changes in behavior that will be required to take up hydrogen technologies; the added benefits they will bring to consumers, their costs, their effectiveness in tackling energy-environmental problems and the overall regulatory-institutional framework in which they will be embedded (Devine-Wright et al., 2017). Acceptance is defined as a favorable or positive response relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (Gaede and Rowlands, 2018). Acceptance always comes after the associated concerns are addressed. The concerns about the attendant risk of hydrogen, with its opportunities and advantages (Ricci et al., 2007) and uncertainties at government and stakeholder levels over the development and application of different technologies (Sherry-Brennan et al., 2010).

Evaluation of perspectives for hydrogen uptake in regular communities or island communities is relevant for community decision-makers who are interested in developing large-scale hydrogen and fuel cell initiatives, and who would benefit from knowing what circumstances or characteristics of the given community will be important for success (Shaw and Mazzucchelli, 2010). There exists substantial literature examining the rates at which technologies have historically diffused into markets (McDowall, 2016) which is the so called 'transition'. The transition from traditional fossil fuel sources towards a low carbon economy addressing hydrogen production, its delivery and conversion technologies. This transition not only requires dedicated research and development but also needs protected niche markets, early adopters (Rogner, 1998) and a surplus supply (Bleischwitz et al., 2010). Policy makers, stakeholders as well as manufacturers therefore have a great interest in understanding these early adopters (Gnann, 2013).
Early adopters are the very first users of any alternative fuel cell technology. Early adopters help policy makers and manufacturers identify the transition drivers like the opportunities to produce cheaper and better energy services (Fouquet, 2010). There are a number of underlying concerns for policymakers in

adopting alternative options such as hydrogen fuel against the conventional fossil fuel economy - in particular, the national economy related to domestic macroeconomic variables and developmental issues (Ahmed et al., 2016).

A number of economists have examined the transition experience in developing economies and have found the backdrops to be socio-economic and environmental constraints (Fouquet, 2010). In developed countries the speed of adoption to overcome many of the barriers are led by strong government support combined with shifts in environmental value (Ambrose et al., 2017). It is undoubtedly the enormous investment required to set up a completely new hydrogen storage and distribution network, which has biased some policy makers and government support against hydrogen as the alternative fuel for transport (Andrews and Shabani, 2012).

The acceptance of any hydrogen FCV depends on its production costs (Ambrose et al., 2017) and stages of delivery and storage to utilization of the hydrogen (Gim et al., 2012). The demand for the estimated hydrogen in the future is not certain because of unobservable data and assumptions (Kim et al., 2008) and also it is not uncommon for new technologies such as hydrogen FCV to face skepticism that may be detrimental to successful market penetration (Al-Amin et al., 2016). Therefore, for a successful transition to a low-carbon society we should consider both the demand-side behaviors like private-sphere, environmental behavior and supply technologies (Poortinga et al., 2012) like infrastructure and technological development.

Other limiting factors for widespread adoption of hydrogen-fueled vehicles, includes lack of economic infrastructure (Lord et al., 2014), achieving social acceptance (Kim et al., 2008), high production costs, storage problems, transport and supply problems, high operational costs (Morris and Radu, 2010) along with individual conditions such as the distance between production and demand (Wulf et al., 2018). Furthermore, purchase intention, consumer environmental concerns and behavior for Hydrogen FCV are additional challenges (Al-Amin et al., 2016). Other than infrastructure and technological development, public perceptions concerning magnitude and distribution of costs and benefits constitute significant market and behavioral barriers for new fuel and propulsion technologies (Kontogianni et al., 2013). This is important as individuals need to change their behavior to comply with policies and accept new low-carbon energy.

3. Methodologies Adopted

There is a plethora of assessments using quantitative modelling to evaluate renewable energy alternatives (Ambrose et al., 2017). Most of the studies carried out show the use of stated preferences for AFV's however there is limited literature applying DCE's specifically to Hydrogen in the tourism sector. Some of the methodologies adopted to analyze public perception, acceptance, production and driving forces are outlined below:

A contingent valuation study conducted in London investigated the preferences of London taxi drivers for driving emissions-free hydrogen fuel cell taxis, both in the short term as part of a pilot project, and in the longer term. The results show that willingness to pay to participate in a pilot project seems to be driven mostly by drivers' expectation of personal financial gains. In contrast, however, environmental considerations are found to affect taxi drivers' longer-term vehicle purchasing decisions. The results also reveal that driving hydrogen-fueled vehicles does not seem to raise safety concerns amongst taxi drivers (Mourato et al., 2004).

Heffner et al. (2007) uses ethnographic interviews to analyze semiotic theory to show how recognized social meanings [denotations] are connected to more personal meanings [connotations] and effect both vehicle purchase and its use. They also state HEVs symbolizes ideas such as environmental preservation, financial responsibility, and independence from petroleum producers; as their construction and communication, is essential for policy makers and others to promote these new types of vehicles. And in turn, this links to other concepts that are relevant to self-identity, such as ethics, intelligence, and independence.

Tarigan and Bayer (2012) willingness to pay study in Norway identified trends in public opinions concerning the introduction of hydrogen vehicles and public attitudes for residing in the proximity of within and outside a 1 km radius of the hydrogen refueling station. Findings revealed that individuals living close to hydrogen refueling stations are more likely to support hydrogen technology features than those who live beyond the stations. The authors further concluded that a "ride and drive" clinic along with refueling stations where participants can experience using hydrogen vehicles could increase knowledge and furthermore improve pro-environment attitudes.

Two survey studies based on willingness to use hydrogen conducted in The Netherlands concluded:

- Knowledge on Hydrogen is not very high.
- Hydrogen is perceived as environmentally friendly and an inexhaustible fuel and not so much as a dangerous fuel.
- Attitudes towards hydrogen is quite positive and the willingness to use hydrogen is rather high.
- Increased costs were a concern for switching to hydrogen applications.
- Perceptions of decreased safety is a key deterrent for the switch to hydrogen (Zachariah-Wolff and Hemmes, 2016).

Yetano Roche et al. (2010) used quantitative consideration for research designs and relatively large sample sizes and some of the in-depth qualitative studies including focus groups and in-depth interviews. Ziegler (2012) used the stated preference discrete choice experiment to examine the preferences for alternative energy sources or propulsion technologies in vehicles and particularly for electric vehicles. They found participants had a higher stated preference for hydrogen and electric vehicles and that environmentally aware car buyers have a higher stated preference for hydrogen and electric vehicles.

Findings from the existing literature on preferences show what a fully-fledged hydrogen economy might entail from a broad range of distinctive methods and applications. The major attributes included in peer-reviewed studies on consumer preferences for AFV's and hydrogen are provided in the following Table 1.

Table 1: Literature Review on hydrogen fuel cell transportation

Year	Study	Location	Model	Fuel and vehicle type	Attributes	Results
2004	(Mourato et al.)	London	CVM	hydrogen fuel cell taxis	Range, Speed, Acceleration, Emissions, Fuel cost, Fuel stations, Operating costs	WTP is driven mostly by drivers' expectations of personal financial gains and environmental considerations are found to affect taxi drivers' longer-term vehicle purchasing decisions.
2005	(Horne et al.)	Canada	DC	Gasoline, AFV, HEV, HFCV	Purchase price, fuel cost, fuel station, emission, incentives,	Market shares for cleaner vehicle types like hybrid-electric and hydrogen fuel-cell were predicted to be higher up to 35% and 49% provide all attributes were equal;
2006	(Haraldsson et al.)	Stockholm	WTP	hydrogen fuel cell buses	Safety, comfort, Price, Frequency, Environment	General public and drivers both are generally positive towards fuel cell buses and feel safe with the technology and 64% of the bus passengers were not willing to pay a higher fee if more fuel cell buses were to be used.

2010	(Yetano Roche et al.)	Germany, London	CVM, WTP	hydrogen fuel cell vehicles	preferences, Environment, knowledge of alternatives and budget.	The quantitative studies on HFCVs revealed low awareness about the technology but generally positive attitude towards it. Also, Willingness to pay, where studied, was positive but not generally influenced by the level of environmental awareness of respondents
2012	(Achtnicht et al.)	Germany	MNL	CFV, NGV, HEV, BEV, FCEV, BV	Purchase price, fuel costs, emissions, fuel availability, performance	Alternative fuel availability influences choices positively, but its marginal utility diminishes with supply. Furthermore, failure to expand the availability of alternative fuel stations represents a significant barrier to the widespread adoption of alternative-fuel vehicles
2012	(Ziegler)	Germany	MNP	CFV, NGV, HEV, BEV, FCEV, BV	Purchase price, fuel costs, emissions, fuel availability, performance	Younger potential car buyers have a higher stated preference for hydrogen and electric vehicles, males have a higher stated choice of hydrogen vehicles, and environmentally aware potential car buyers have a higher stated preference for hydrogen and electric vehicles

2013	(Hackbarth and Madlener)	Germany	MNL, ML	CFV, NGV, HEV, BEV, FCEV, BV, PHEV	Purchase price, fuel costs, emissions, driving range, fuel availability, refueling time, incentives	Younger, well-educated, and environmentally aware car buyers are willing to pay considerable amounts for greater fuel economy and emission reduction, improved driving range and charging infrastructure, as well as for enjoying vehicle tax exemptions and free parking or bus lane access
2013	(Beck et al.)	Australia	LCM	CFV, HEV	Purchase price, fuel costs, performance, vehicle type, registration and emissions charges, fuel efficiency, number of seats country of origin	Choice of vehicle purchase is based on classes of response behavior and are influenced by their attitudes and socio-demographics.
2014	(Hoen and Koetse)	Netherlands	MNL, ML	CFV, NGV, HEV, BEV, FCEV, BV, PHEV	Purchase price, fuel costs, driving range, refueling time, incentives, additional detour time, number of models	Preference for AFVs increases considerably with improvements on driving range, refueling time and fuel availability and willingness to accept is on average € 10,000–€ 20,000 per AFV; Logit models confirm that consumer preferences for AFVs and AFV characteristics are heterogeneous

2016	(Hackbarth and Madlener)	Germany	DCE, WTP, CV	CFV, NGV, HEV, BEV, FCEV, BV, PHEV	Purchase price, fuel costs, emissions, driving range, fuel availability, refueling time, battery recharging time, incentives	1/3 of the consumers are oriented towards at least one AFV option; German car buyers willingness-to-pay for improvements of the various vehicle attributes varies considerably across consumer groups and that the vehicle features have to meet some minimum requirements for considering AFVs
2016	(Fúnez Guerra et al.)	Spain	DCE, MNL	CT, NGV, HEV, PHEV, BEV, BV, FCEV	Purchase price, fuel cost, emissions, driving range, fuel availability, refueling time	With fuel cost increased by 50% for CT, NGV, HEV and BV, the CT and HEV vehicles decreased in sales and the MMNL results reflects lack of incentive to purchase an AF vehicle in small cities with inadequate infrastructure
2017	(Yang et al.)	Korea	CVM, WTP	HFCEVs and fueling station expansion	Gender, Specified bid for expansion, Income,	The mean yearly WTP was computed to be KRW 2258 [USD 2.04] per household. The national value of the H2 station expansion policy amounts to KRW 42.8 billion [USD 38.6 million] per year for the next ten years. This shows Korean households have revealed that they are willing to accept a share of the financial burden of expanding the H2 station policy

3.1 Discrete Choice Experiment Applications

Designing a discrete choice experiment involves four important decisions, they include identifying relevant attributes, deciding the number and values of the discrete levels of each attribute, how many alternatives to include in a choice set and creating an experimental design where the values of attribute levels are uncorrelated or weakly correlated both within and between alternatives. (Ewing and Sarigöllü, 1998, Hoen and Koetse, 2014, Hidrue et al., 2011). In order to forecast the demand for a new product or transport innovation, we require information on consumer's preferences in the current market (Brownstone et al., 2000). This involves asking respondents to indicate their preference among two or more multi-attribute alternatives (Johnston et al., 2017). The results reveal consumers underlying latent preferences and the potential factors that affect demand for clean-fuel vehicles using real-world choices (Ewing and Sarigöllü, 1998).

Fúnez Guerra et al. (2016) used discrete choice models in Spain to forecast alternative fuel vehicles sales. The study shows that refueling infrastructure acts as a constraint on the choice set for vehicle buyers. The authors also identified important factors such as; purchase price, operating costs, driving range and fuel availability that have substantial effects on consumer preferences for AFVs. Other important factors include; emission reduction, purchase price, fuel cost, CO_2 emission, driving range, fuel availability and refueling time.

Hidrue et al. (2011) used a choice experiment wherein 3029 respondents were asked to choose between their preferred gasoline vehicle and two electric versions of that preferred vehicle. The results of a latent class random utility estimated the willingness to pay for five electric vehicle attributes: driving range, charging time, fuel cost saving, pollution reduction, and performance. Tanaka et al., (2014) conducted a comparative discrete choice analysis to estimate consumers' willingness to pay [WTP] for electric vehicles and plug-in hybrid electric vehicles in the US and Japan in 2012. The results showed that on average US consumers are more sensitive to fuel cost reductions and alternative fuel station availability than Japanese consumers. Results of stated preference studies like DCE's are central components of formal and informal policy analyses, natural resource damage assessments, litigation, decision making by firms, advocacy by NGO's and in the valuation of changes in ecosystem services, transportation, health, marketing, etc., (Johnston et al., 2017).

Table 2: Preferences

	Fuel Cost	O&M Cost	Emissions	Purchase power	Recharge time	fuel availability	Range	Policy Incentives
Potoglou and Kanaroglou (2007)	*	*	*	*		*		*
Hackbarth and Madlener (2016)	*		*	*	*	*	*	*
Hoen and Koetse (2014)	*	*		*	*	*	*	*
Hackbarth and Madlener (2013)	*		*	*	*	*	*	*
Ziegler (2012)	*		*	*		*		
Hidrue et al. (2011)	*		*	*	*		*	
Ewing and Sarigöllü (1998)	*	*	*	*	*		*	
Achtnicht et al. (2012)	*		*	*		*		
Beck et al. (2013)	*		*	*				
Parsons et al. (2014)	*		*	*	*		*	

3.1.1 Choice Attributes in the Literature

Choices play a crucial role when selecting any vehicle. Caulfield et al [2010] states, a consumer follows a thorough investigation before any decision-making. Each consumer goes through the process of problem recognition, information search of external and internal criteria based on their preferences Then does an evaluation and then selects among k number of choices including the alternative vehicle choice and makes a final decision to purchase/rent a vehicleThis behavior is not limited to just pre-purchase or pre-rent, the customer keeps evaluating the product or the rented car, which can be stated as post purchase behavior.

It is quite complex to identify the exact motivation behind this decision making. Ozaki and Sevastayanova (2011) states that the motivational constructs attached to the adoption of hybrid vehicles fall into five groups. The first group relates to financial benefits and other policy-related advantages. The second group relates to a particular symbolic meaning attached to hybrid cars: environmentalism. The third group is concerned with compliance with the norms of the community. The fourth group is intrinsically attracted to new technology. The fifth group of consumers is concerned with achieving independence from oil producers through reduced petrol consumption.

These behaviors are intended to influence consumers decision making process and opting for a conventional or any AFV. Findings from Table 2 suggest that fuel cost and purchase power have the most substantial effect on consumers preference while selecting an AFV. Emission reduction stands second with Recharge time, fuel availability and range in the third. Some of the literature also suggests that policy incentives like vehicle tax exemptions, free parking and the allowance for bus lane usage, which aggregate to €3.18 and €4.34 for the monetary and the non-monetary governmental incentives also play a crucial role while choosing an AFV vehicle (Hackbarth and Madlener, 2016).

Although Operation and maintenance costs do not have a substantial effect on vehicle purchase decision it is still an important factor to be considered. This shows the relationship between the possibilities produced by technological innovations and actual sustainable outcomes is heavily mediated by consumers' attitudes towards those innovations Ozaki and Sevastayanova (2011). We acknowledge that consumers' willingness to purchase non-conventional vehicles differs from willing to rent the same.

The choice variables outlined in the following section provide information on common considerations in relation to using AFV's and insights into consumer's preferences when making purchase decisions:

a. Frequency of Visits

Since the tourists travel by air travel or ferry travel first and then by internal roads, we can assume the choice of travel zone is usually based on the distance to the site [Gonzales, 2018]. This not only helps us to validate the frequency of flyers but also helps us to identify their preference for mode of transport on the road.

b. Fuel availability

Fuel availability plays an important role in consumer's decision making. Authors like Martin and Rice (2012) states, lack of fuel availability and refueling station constitutes a barrier in the adoption of alternative-fuel vehicles, creating a complementary relationship between vehicle demand and fueling infrastructure availability, often described as a ''chicken-and-egg'' problem.

c. Emissions

Beck et al [2013] states the economic answer of pricing negative externalities could result in emission reduction. i.e., a carbon emissions price that effectively results in an increase in the price of petroleum-based fuels has the potential for lowering fuel demand, thus reducing emissions. Some of the influencing factors in decision making may include awareness of climate change and global warming, decreasing natural resources consumption, preservation of the environment, reduction in pollution level, mitigation of personal ecological footprint, being a trend setter of pro-environmental technologies and being part of socially responsible activities (Ozaki and Sevastayanova 2011).

d. Recharge time

Recharge time or charging time can be defined as the time needed to charge the battery for a set distance [Hidrue 2011]. This recharge time invariably ranges between conventional and non-conventional vehicles. Recharging time ranges from 30 min-90 min to 6 hrs. to 8 hrs. [Hoen et al., 2014, Hackbarth and Madlener 2013] to allow for a wide range of possible future values and for heterogeneity in recharge technology.

e. Range

It is evident that range is the primary impediment to adoption of battery-powered EVs for any multipurpose transportation [Ewing and SarigoÈ lluÈ, 1998], since the driving ranges of hybrids, plug-in hybrids and flexi fuel vehicles do not differ from that of conventional cars [Hoen et al, 2014], we can assume range itself will not be an overriding limitation to the adoption.

f. Policy incentives

Incentives can be described as advantages or rewards that households would gain with the purchase of a hybrid electric or an alternative fueled vehicle. There is potential for rental car owners to access the same advantages or rewards. Policy incentives are the Non-monetary attribute and may include elimination of vehicle sales tax, free parking and permission to drive on high occupancy vehicle, lanes, [Dimitri, 2007], pay less for fuel, other government incentives, free access to town center, tax payback, permission to drive in the carpool lane and unaffected by fuel price fluctuation (Ozaki and Sevastayanova 2011).

g. Car Type

Based on their preferences, consumers tend to maximize their utility by selecting among k number of choices. The first step is to identify the types of cars included among conventional technology as well as renewable resource energy types. Choices include Petrol, Diesel, Electric, NGVs, HEVs, PHEVs, BEVs, BVs, FCEVs. And the last step is chosen among the number of other attributes like number of seats, small, medium or big vehicles, etc.

h. Purchase Power

Hoen et al [2014] states, the purchase price of any AFV is usually equal to the price of the current technology plus a design dependent mark-up. The mark-up of the electric vehicle also dependent on the vehicle driving range since higher driving range requires a larger battery pack with higher associated costs. The prices quoted by authors like Hoen et al [2014], Brownstone et al, [2004] ranges between €9000 and €100,000.

i. Monthly Costs

Monthly costs usually comprise; fuel Costs, maintenance costs, service station fuel cost and road taxes [Hoen et al, 2014], [Brownstone et al, 2004]. These annual fuel costs are usually computed as the product between the reported annual usage rate [in km/year] and the average fuel cost per kilometer [in cents/km], specific to the selected class/size category [Dimitri, 2007]. Maintenance cost, service costs and road taxes vary according to the location.

j. Experience

Schulte (2004) states prior experience is a key factor by which public attitudes can be changed. And a study conducted by Martin et al (2009) in accordance with University of California, show any prior knowledge and experience with AFV's has high influence on decision making, and their behavior changes towards alternative fuel vehicles as they gain experience.

These attributes (A-J) outlined above are not limited but provide insight on the choice considerations of a decision maker. The preferences may also depend on; body type, engine displacement, fuel efficiency, fuel Price, class, size and acceleration [Dimitri, 2007]. It is important to identify the motivational factors for the considerations of the decision maker. However, Ozaki and Sevastayanova (2011) includes some of the motivational factors for any purchase, and we attempt to assume the applicability of the same motivational factors even for renting the vehicle. They include being considerate to others, attracted to new technologies, being a pioneer in the technological sphere, educating others about a new type of vehicle, sharing technological knowledge, enjoying the benefits of the innovation, doing the right thing, sharing a common ideology within the community and independence of oil producers.

4. Conclusion

The main aim of work package 7 on the SEAFUEL project is to identify tourists' preferences for hydrogen fuel cell rental cars. Preferences for FCV rental are quite different to preferences to purchase a FCV and to date the literature on the former is limited. In terms of rental demand, we have established that numerous factors influence consumer preferences of AFV such as information, experience, fuel source, vehicle running costs, safety concerns and refueling infrustructure. Preferences for technology, driver experience, sociodemographics social norms and details on a respondent's holiday experience and aspirations will also matter particularly in terms of explaining why subjects make rental choices. Building on this literature review our work suggests that *Information, knowledge* and *experience* are particulalry important issues in identifying early adopters and in understanding diffusion from early to late adopter groups. These will be tested, evaluated and further refined in focus groups, then piloted and captured in a survey instrument. Subsequently data and modelling using a discrete choice experiment will yield findings to enable policy makers to design effective economic instruments and incentives targeted at early adopters to increase market share of AFV in the tourism rental market.

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