

## Climate change perception, behaviour, and willingness to purchase alternative fuel vehicles: the missing dots

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### ABSTRACT

This paper explores the correlation between respondents concerns regarding climate change, their eagerness to adopt an AFV and their responsiveness to incentives. Seen as the solution for a cleaner mobility and greenhouse gas reduction in urban areas globally, alternative fuel vehicles (AFV) still own a modest market share in Europe. Among many reasons, the purchase price seems to be one of the most challenging to overcome. Incentives are considered a solution to mitigate the price barrier. The results of a survey carried out by the authors to 444 respondents led the authors to conclude that participants agree that AFVs contribute to tackle climate change. They also deduced that the vehicles price represents an offside for the lower-income households. Furthermore, the study revealed that the latter are less prone to buy an alternative fuel vehicle than higher-income families (59% against 80%). The authors also inferred that generally, households are more receptive to incentives or benefits based on up-front discounts or exemptions, directly impacting price and immediate savings, such as taxes exemption (value added tax and circulation tax), fuel discounts and purchase incentives. However, some differences were observed between income segments. For instance, the reduction or exemption of loan interests is among the most popular incentives for lower revenues, whilst higher revenues favour scrappage and non-financial incentives. Finally, in line with other studies, as upper incomes are less dependent on incentives and benefits to carry out the purchase, the authors put forward a differential and progressive approach for incentive instruments targeting lower revenues, allowing broader and equitable access to low carbon technology.

### Keywords

Sustainable mobility;  
Alternative fuel vehicles;  
Vehicles adoption;  
Incentives and benefits;  
Climate change

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### Abbreviations

AFV	Alternative fuel vehicle	ICEV	Internal combustion engine vehicle
BEV	Battery-electric vehicle	HEV	Hybrid electric vehicle
EAFO	European alternative fuel observatory	LPGV	Liquid petroleum gas vehicle
FCEV	Fuel cell electric vehicle	PHEV	Plug-in hybrid electric vehicle
		VAT	Value added tax

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## 1. Introduction

Perceived environmental benefits from driving alternative fuel vehicles (AFVs) rather than internal combustion engine vehicles (ICEVs) powered by petrol or diesel are increasing. In addition, people's perception of climate change's consequences and environmental issues enhances the need to shift towards greener mobility. Hence, manufacturers widely use this argument to incentivise the AFVs' adoption, but it seems to come with few boosting effects. Despite the critical role that alternative fuel vehicles will expectantly play in reaching the carbon neutrality goals, they still face environmental, social, economic, technical, and political challenges.

Albeit an increasing trend over the last decade, the percentage of alternative fuel (AF) passenger cars in UE's fleet is nevertheless relatively modest: 4.91% year today (EAFO, 2021). Currently, AFVs are at a production cost disadvantage, due to the cost of the battery but also due to technological developments, which implies a significant burden on the vehicle's purchase price. Therefore, the adoption rhythm must accelerate further and production must scale up to allow prices to decrease. However, to that aim, the AFVs should become more affordable.

Additionally, as for any recent technology, the diffusion commonly requires government's intervention through policies' instruments and subsidies. In this case, the role of policies is to favour the adoption either by offering attractive financial or non-financial incentives or by taxing fossil fuels to slow down the purchase of conventional ICEVs. However, considering that the latter remains a familiar and mature technology and, overall, very cost-effective, it is obvious that alternative incentives instruments are required to raise the adoption rate.

Within this framework, the goals of the study are threefold: 1) to infer the relation between climate change concerns and mobility behaviour, 2) to assess the prevalence of climate change issues perception in the AFVs' purchase intention and, 3) to identify the instruments and the policies' pathways with potential to mitigate the financial barriers. In that sense, this paper explores the following research questions: Can we establish a correlation between climate change perception, mobility behaviour change and AFVs adoption willingness? Why are AFVs price boundaries beyond the reach of the average citizen? Which incentives could help overcome the cost gap between AFVs and ICEVs?

This article is structured as follows. Section 2 presents a literature review. Section 3 describes the research methodology, including the conceptual framework of the study, data gathering and analysis. Section 4 outlines and discusses the major findings. Section 5 summarises the conclusions and points out future research.

## 2. Literature overview

As diesel and petrol-powered ICEVs are being steadily pushed out of the market, alternative fuel vehicles such as hybrids mainly plug-in (PHEV), battery-electric (BEV) and fuel cell electric (FCEV), claim to be the most promising mobility solutions to decarbonise light-duty transportation and to contribute to climate change tackling. The pathway to reduce emissions effectively relies on a wider AFVs diffusion combined with the development of a resilient renewable energy system [1] and the reduction of electricity importation [2]. According to Schwirplies [3], climate change mitigation encompasses all measures to abate greenhouse gas, for instance a more environmentally-friendly behaviour or the adoption of green technologies enabling carbon dioxide (CO<sub>2</sub>) reduction. It includes the transition towards greener mobility means.

People's willingness to adopt green technology is distinctly affected by environment issues and climate change perception, beliefs and awareness, and knowledge [4, 5, 6], being a significant predictor of intention to adopt mitigation measures [3, 7, 8]. In addition, media, social norms, geographical region, economic development, and individual experience also affect the understanding of climate phenomena [9]. The more individuals are impacted by climate change effects, the more they perceive the corresponding threat [10] and the more they are willing to take action.

However, AFVs' adoption is more than a specific example of green technology diffusion, as some distinct issues arise. While some authors positively correlate environmental and climate change beliefs with AFVs sales [4, 11, 12] others argue that neither the pro-environmental behaviour [13] nor the environmental awareness [14, 15] influences consumers' intention to purchase AFVs.

Furthermore, considering that vehicles are frequently the second largest investment, after housing, for most households, peoples' choice is also highly conditioned by financial factors. On top of many barriers, such as technical, psychological, and symbolic, among others,

several studies point out household income as one of the principal determinants in AFVs purchase decision-making [16, 17, 18, 19]. Despite a cross-cutting concern regarding environmental and climate change issues transverse to all households [20], wealthier families are more likely to buy an AFV [19] than large or lower-income ones. Moreover, they instead choose an AFV (Hybrid or Battery electric) over a conventional one, such as a petrol-powered vehicle [21].

Along with the household income, many authors have identified purchase price as the main barrier to AFVs adoption [12, 22, 23, 24, 25, 26, 27, 28] and a reason for the slow uptake [29]. Many studies argue that without a price decrease, the demand for AFVs will not grow, and the economy's scale effect, which allows prices to drop, will hardly be reached.

On average, a new PHEV, BEV and FCEV costs up to 35%, 50% and 100%, respectively, more than the equivalent conventional ICEV (Statista: "Average purchase price of new passenger cars in 2020 in the Netherlands"). Currently, in Europe, there are different paces and stages in AFVs' adoption. For instance, while Slovenia registered a share of 3,9% of new AFVs' in 2021, Sweden or Norway had a share of 42,5% and 86% respectively (EAFO, 2021). Some authors have highlighted the relevance of incentives and benefits to mitigate the initial investment and establish a correlation between an adequate policy and a reasonable adoption rate [30]. The research achieved by many authors showed that incentive programs highly promote or influence the intention to buy AFVs [30, 31], especially among young people [32]. Incentives, particularly the financial ones, have proven to be a powerful lever, essentially in an early launch phase [33]. There is an undeniable correlation between a low adoption trend in some countries and the lack of local incentives policies [19]. In the same way round, a study in Slovenia concerning BEVs adoption showed that purchase price subsidies and free parking are the most prevalent factors to boost the adoption [26].

According to Wang and Matsumoto's research [21], the Eco-car program launched in Japan had a meaningful impact on families' purchase decision-making between an HEV and a conventional vehicle. A study achieved in Norway, where BEVs and PHEVs represent 21% of the total passenger cars fleet, found that without incentives, only 23% of owners would have purchased them [34]. Meanwhile, in Norway, which has a share of 85,6% for new AFVs registration (EAFO, 2021), mainly BEVs, the up-front price reduction combined with a

competitive purchase price is considered critical in the adoption rate success [35], which is not the case for the other European counterparts.

Another research achieved in Ireland evidenced that despite several incentives, affordability is the primary determinant for BEVs purchase [8]. However, a study realised in Sweden, one of the "best in class country" in terms of BEVs' adoption, also demonstrated that nonetheless the satisfactory outputs for BEVs in Sweden linked to local infrastructures policies and direct subsidies, the authors believe they are still too costly for households [17], leading to a slow uptake.

Whereas the chasm between mentioned countries, it is worthwhile to understand better how environmental concerns affect consumers' mobility patterns and intentions towards AFVs adoption. It is also critical to grasp if the lack of competitiveness impacts the adoption rate and comprehend which measures and instruments could mitigate the gap.

To the best of our knowledge, the past literature does not identify the missing dots between the climate change concerns, mobility behaviour, and the AFVs purchase intention. Therefore, in this research, the authors address this issue by assuming that the missing dots lie in the lack of a segmented incentives policy to fill the gap between the will and the achievement of purchase and put forward pathways according to stated preferences and study findings.

### **3. Research methodology**

This paper aims to understand better the missing dots between climate change concerns, behaviour and the willingness to purchase an AFV. Based on the assumption of the expensiveness of AFVs compared to ICEVs, the authors studied the preferred incentives and benefits to mitigate the price barrier.

#### **3.1. Proposed Research Mode**

The authors tested six hypotheses of correlation between socio-demographic characteristics, climate change perceptions, mobility behaviour and willingness to purchase an AFV.

- H1. Climate change perceptions vary according to socio-demographic factors.
- H2. Socio-demographic factors distinctly affect people intention to change mobility behaviours
- H3. Socio-demographic factors distinctly affect people's willingness to purchase AFVs.

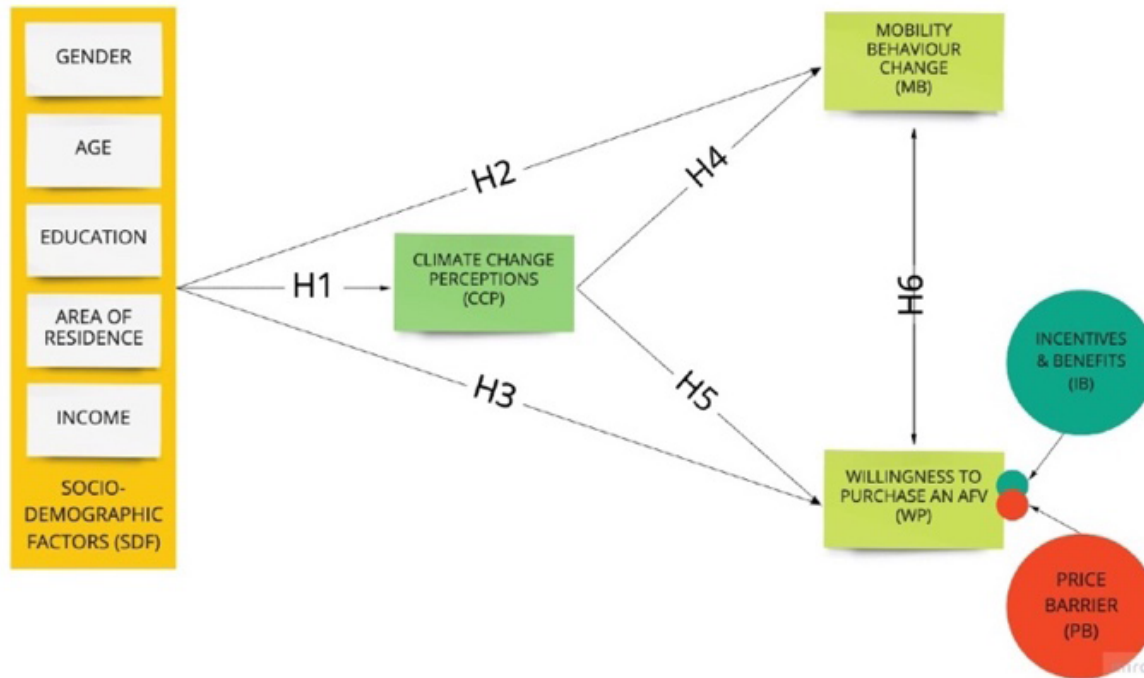


Figure 1. Research conceptual framework

- H4. Climate change perceptions distinctly influence people’s intention to change mobility behaviours.
- H5. Climate change perceptions distinctly influence people’s willingness to purchase AFVs.
- H6. Willingness to purchase AFVs is correlated to the intention to change mobility behaviours.

The research model developed (Figure 1) provides a synthetic and visual overview of the research goals and recaps the proposed relationships.

### 3.2. Data Collection and Measure

The research was based on a survey applied between September and December 2021 to 689 individuals over 17 years old. The authors validated the answers received from respondents aged 17, as they considered that the latter have easily access to the necessary knowledge to answer the survey.

The participants were contacted via their social media accounts (Facebook, LinkedIn, and Instagram) and e-mail and asked to answer close-ended questions and multiple-choice questions. The opinions were measured with a Likert scale varying from 1 (strongly disagree) to 5 (strongly agree).

In this study, the authors used a non-probability convenience sampling technique for data gathering [36].

The authors collected 598 answers, of which 438 completed surveys. According to Green [37], a minimum sample size  $N > 50 + 8m$  (where  $m$  is the number of independent variables) is needed for testing multiple correlations and  $N > 104 + m$  for testing individual predictors. Therefore, according to this recommendation and considering that this work has 23 independent variables, our  $N$  should be larger than 234, which was the case.

Descriptive analysis concerning socio-demographic factors, general environmental and climate change beliefs and attitudes and willingness to change car travel behaviour, including the intention to adopt an AFV, were carried out using several parameters for the distribution of variables, namely frequency and percentage.

The normal distribution was analysed by the Kolmogorov-Smirnov and Shapiro-Wilk test, confirming a non-normal distribution. Nonparametric tests were applied, namely Kruskal-Wallis, Jonckheere-Terpstra, and Mann-Whitney U tests, to determine the assumption of normality between groups and a Friedman test to evaluate the differences in the proportions between the chosen incentives and benefits. Spearman’s and Kendall’s tau-b correlation analysis were performed to assess the correlation between socio-demographic factors and climate change dimensions, mobility behaviour and willingness to buy an

AFV, between climate change dimensions, mobility behaviour and willingness to buy an AFV and finally between willingness to buy an AFV and mobility behaviour.

Statistical analyses were performed using the software IBM SPSS Statistics 27.

#### 4. Major findings

In this section, the authors highlight the major findings of this study. After a descriptive analysis, an exploratory factor analysis was performed to group and reduce the number of factors related to climate change beliefs, followed by hypothesis testing to infer the correlations between variables. A Categorical Principal Components Analysis (CATPCA) was achieved to reduce the number of incentives and benefits variables. A Friedman test was ran to obtain a rank.

#### 4.1. Descriptive Analyses

Table 1 reports a summary of the main characteristics of the sample.

The majority of the participants (56%) were males, 43.6% females and 0.4% others. 30% of the respondents belonged to the age group of 46–60 years (49%), followed by the age group of 36–45 years (24%), 17–25 and 26–35 years (both 21%) and more than 60 years (3%). Most respondents were graduates or postgraduates (76%), while 24% did not own graduation (Table 1).

Almost half of the respondents (41%) reported an annual family income of 15,000 to 30,000 euros, followed by 27% of respondents with a family income lower than 15,000 euros. On the other hand, 32% indicated an income higher than 30,000 euros. Concerning residence location, 87% live in the most densely populated areas, and the remaining 13% live in less densely populated areas. More than 35% reside in the city’s centre, 39% in the city’s periphery, and 26% reside in rural areas (Table 1).

Table 1. Socio-economic characteristics of the sample

Variables	Category	Frequency (N=189) (N=189)	Percent
Gender (N=443)	Male	248	56%
	Female	193	43.6%
	Other	2	0.4%
Age (N=444)	17 - 25	93	20.9%
	26 - 35	93	20.9%
	36 - 45	108	24.4%
	46 - 60	135	30.4%
	More than 60	15	3.4%
Residence (N=444)	Center of a big city	157	35.3%
	Periph. of a big city	173	39.0%
	Rural area	114	25.7%
Household Income (N=438)	< 15,000€	104	23.8%
	15,000 30,000€	174	39.7%
	30,000 45,000€	82	18.7%
	45,000 60,000€	39	8.9%
Education level (N=444)	> 60,000€	39	8.9%
	Junior School	10	2.3%
	Secondary Education	99	22.3%
	Graduate Degree	166	37.3%
	Master’s degree	143	32.2%
Area density (N=444)	PhD Degree	26	5.9%
	≥150 h/km <sup>2</sup>	388	87.4%
	<150 h/km <sup>2</sup>	56	12.6%

Respondents were inquired about their opinions on 20 items regarding climate change beliefs and perceptions. The overall aim was to assess participants' awareness of the phenomena, their concerns, their perception of the effectiveness of individual and collective efforts, their information needs and credibility perception, and their perception of policies effectiveness. In short, globally, respondents think that global warming is a serious issue and more than 80% feel that it threatens their health and life; therefore, it is essential to tackle it (75%).

According to respondents, global warming results from human action/activity (more than 80%) and leads to extreme climate phenomena. 98% believe that collective efforts are efficient, but they are less confident regarding individual efforts effectiveness (73%). 60% of respondents agreed that this topic is discussed frequently within family or friends circle and often see or hear news about it. Nonetheless, near 70% of participants agreed on climate change news credibility. Less than 50% of respondents are convinced of environmental policies effectiveness.

Mobility behaviour and willingness to purchase an AFV were assessed thanks to following items: "I intend to avoid unnecessary travel by car (MB1)", "I intend to avoid using my car only for short distances (MB2)", "I intend to choose another way of travelling, like walking, cycling, public transports" (MB3). They gathered respectively the agreement (agree and strongly agree) of 71%, 61% and 63% of respondents. In addition, 67% of participants agreed with the statement "I intend to buy a more environmentally-friendly car" (WP), confirming a comprehensive will to adopt AFVs.

#### 4.2. Factorial Exploration of Climate Change Perception Variables Structure

The authors achieved an exploratory factor analysis (maximum-likelihood method, varimax rotation) on the

20 climate change beliefs items (N=598). Nineteen items were retained, producing four factors (Table 2) related to four dimensions of climate change:

1. Impact perception (IP)
2. Causes perception (CP)
3. Action and Effectiveness (AE)
4. Information sources and Credibility (IC)

After the descriptive analysis, KMO's measure of sampling adequacy and Bartlett's test of sphericity were calculated to examine the reliability and validity of the scales (Table 2).

The reliability test Cronbach's alpha to assess the four climate change dimensions (IP, CP, AE, IC) delivered a score of .907, suggesting an excellent internal consistency. Finally, the normality of climate change factors was evaluated with a Kolmogorov-Smirnov/Shapiro-Wilk test showing a non-normal distribution.

#### 4.3. Hypothesis Testing and Correlations

Hypothesis testing led us to deduce that the correlation between gender (Kruskal Wallis test,  $p < .050$ ), the population density of the residence area (Mann-Whitney U test,  $p < .050$ ) and the way people perceive the different dimensions of climate change is statistically significant and confirmed that there is a linear relationship (Table 3).

Concerning the age groups, the authors observed divergences in their respective sources of information, and their perception of credibility is statistically significant (Kruskal Wallis test, significance level  $p < .050$ ).

Within the gender group, main variations were observed between female and male respondents (others category results were not considered,  $N=2$ ). In all dimensions of climate change, women are keener to agree than men, evidencing higher sensitivity regarding climate change dimensions.

Table 2. Climate change beliefs and perceptions factorial analysis

Factors	KMO Measure of	Bartlett	**KS Test of Normality					
	Sampling Adequacy*	Sphericity	Kolmogorov-Smirnov	Shapiro-Wilk				
	Loading	Sig.	Statistics	df	Sig.	Statistics	df	Sig.
Impact perception (IP)	.81	<.001	.143	598	<.001	.849	598	<.001
Causes perception (CP)	.76	<.001	.092	598	<.001	.879	598	<.001
Action & Effectiveness (AE)	.66	<.001	.186	598	<.001	.878	598	<.001
Information sources & Credibility (IC)	.66	<.001	.117	598	<.001	.857	598	<.001

\*Cronbach's: 0.907 / \*\*Kaiser-Meyer-Olkin (KMO)

Table 3. Correlations overview

Hypothesis	Variables	IP	CP	AE	IC	MB1	MB2	MB3	WP	Decision
H1, H2, H3	Gender	.137**	.177**	.126**	.146**	.122**	.192**	.155**	-	H. null rejected
	Age	-	-	-	.127**	-	-.168**	-	-	
	Education	-	-	-	-	.124**	-	-	-	
	Income	-	-	-	-	-	-.168**	-.155**	.079*	
	Area density	-.119*	-.106*	-.159**	-.121*	-	-	-	-	
H4, H5	IP	-	.579**	.645**	.633**	.305**	.195**	.291**	.337**	H.null rejected
	CP	-	-	.560**	.524**	.271**	.246**	.265**	.198**	
	AE	-	-	-	.759**	.282**	.180**	.252**	.289**	
	IC	-	-	-	-	.258**	.166**	.245**	.335**	
H6	WP	-	-	-	-	.175**	.135**	.220**	-	H.null rejected

\*\* . Correlation is significant at the 0.01 level (2-tailed). | \* . Correlation is significant at the 0.05 level (2-tailed).

In what concerns the relationship between age and the information source and credibility, the main variances lie in the concernment reflected in the attentiveness to the news and the sharing with family and friends observed in elder groups (45-60 and >60), while youngers (up to 25) evidenced more confidence in news credibility and environmental policies.

The authors also detected statistically significant differences between participants living in areas with higher population density and those living in lower population density. The latter means revealed lower scores, expressing less sensitivity about climate change issues, assuming they are less exposed to environmental issues and urban air pollution.

Hypothesis testing led to several correlations' establishment between variables (Table 3). Kendall's tau-b correlation was performed to find the correlation between socio-demographic factors and climate change dimensions (IP, CP, AE, IC), mobility behaviour (MB1, MB2, MB3) and willingness to purchase an AFV (WP). The correlation between gender and climate change dimensions and mobility behaviour was statistically significant ( $p < .01$ ), although no correlation was found regarding WP.

Regarding the correlation between income and mobility, the authors encountered a negative statistically significant correlation ( $p < .01$ ), revealing that people are less eager to change mobility behaviours as income increases. On the other hand, a positive correlation between income and willingness to buy an AFV was found, which was statistically significant ( $\tau_b = .079, p = .05$ ), indicating a proportional increase of the will as we move to higher incomes.

Table 4. Respondents willing to buy an AFV versus income

Income €	N	Mean	Assent*
Up to 15,000	104	210	59%
15,000 30,000	174	212	66%
30,000 45,000	82	229	68%
45,000 60,000	39	233	74%
> 60,000	39	248	80%

Spearman's correlation was applied to determine the relationship between climate change dimensions (IP, CP, AE, IC), mobility behaviour (MB1, MB2, MB3) and (WP). There was a strong, positive correlation between the four climate change dimensions and the intention to change mobility behaviour, which was statistically significant ( $p < .01$ ). In addition, a strong and positive correlation between willingness to purchase an AFV and mobility behaviour was found ( $p < .01$ ).

To connect the dots and further understand the relationship, the authors analysed the respondents' means and assent percentage (\*agree and strongly agree) among each income group.

The results reveal variances between the income groups, although in line with the statistically significant correlation established ( $p=.05$ ) in Table 4. The purchase intention rises proportionally with the income; therefore, the authors infer that the available revenue shapes the purchase decision-making process.

Based on previous studies outputs, financial (F) and non-financial incentives or benefits (NF) were proposed to the survey's respondents who had to choose the three most attractive incentives among several options. A Categorical Principal Components Analysis (CATPCA)

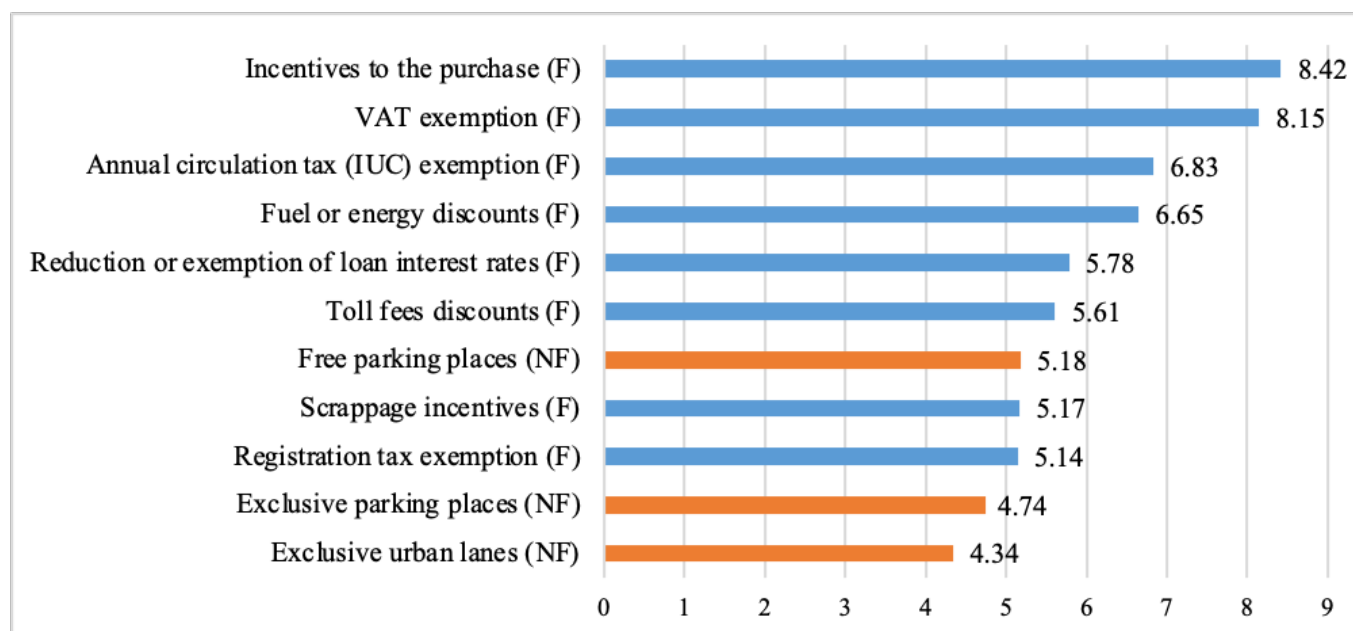


Figure 2. Incentives and Benefits means rank (Data source: the authors' survey)

was carried out using the IBM-SPSS program, version 28, for data reduction, creating a variable output for each group of type of incentive (i.e. VAT reduction or exemption). Afterwards, a Friedman test was ran to obtain a rank showing the mean rank for each of the related groups. The test delivered a statistically significant difference in the type of incentives chosen,  $\chi^2(10) = 1135.084$ ,  $p = 0.000$ .

As shown in Figure 2, the incentives or benefits with higher means are all financial types: “Incentives to the purchase” (8.42), “VAT exemption” (8.15), “IUC exemption” (6.83), “Fuel or energy discounts” (6.65) and “Loan interests’ reduction or exemption” (5.78). The non-financial benefits were the least chosen. The “Free parking” benefit (5.18) was the highest-ranked among the latter.

Finally, the authors identified statistically significant differences (Friedman’s test,  $p = <.001$ ) between incentives and benefits options within the gender, age, and household income groups. For example, women selected “Registration and IUC tax exemption”, “Free parking” and “Exclusive parking places”, “Loan interests’ reduction or exemption”, and “Fuel or energy discounts” whereas men chose “Purchase and Scrappage incentives”, “VAT exemption”, “Toll fee discounts” and “Exclusive urban lanes”. Regarding the variances between age groups, the younger selected mainly exemptions and discounts (registration tax and loan interests’ exemption, fuel

and toll discount, and exclusive parking and lanes). In contrast, elders choose purchase and scrappage incentives, and VAT exemption. Finally, regarding incomes differences, whilst lower revenues elected “IUC exemption”, “Registration tax exemption” and “Loan interests’ reduction or exemption” and Discounts (fuel and tolls), higher revenues selected “Purchase incentives”, “VAT exemption” and non-financial incentives (free parking, exclusive places, and lanes).

### 5. Conclusion and future research

In this paper, the authors undertook a study to link the dots between climate change perception, behaviour, and willingness to adopt AFVs.

The literature review highlights the added value of an interventive policy, namely in an early diffusion phase, to overcome the purchase price gap between alternative and conventional fuel vehicles, explaining the success of the transition towards AFVs in some European countries (such as Sweden and Norway). But the state-of-the-art review does not identify the missing dots between the climate change concerns, mobility behaviour, and the AFVs purchase intention. This article provides a connection between these three aspects of the adoption of green mobility means.

A first analysis led to the conclusion that people seem to be fully aware of climate issues, they evince concern,



and they show eagerness to shift to greener habits and adopt AFVs. The correlation between climate change perception and AFVs purchase intention is consequently supported. However, past studies highlighted that the alternative fuel vehicles' total cost of ownership is a bottleneck [12, 13, 22, 35], one of the most decisive among all barriers, which holds back the adoption rate.

As for any innovation or recent technology launch onto the market, the manufacturers' research and development investment are supported by the early adopters' critical mass, generating an effect of economies of scale on production costs and leading to a reduction in per-unit fixed cost. In the case of alternative fuel vehicles, namely PHEV, BEV, and FCEV, as the vehicle price is hardly bearable by most European households, the critical mass threshold has not yet been reached.

Our results led us to infer that lower incomes are less inclined to buy an AFV. However, the willingness increases as the income rises, which establishes a direct causal relationship between the income level and the intention to buy, consistent with previous related studies [12, 38]. A family with an income of up to 30,000 euros (representing 63% of respondents) will scarcely invest in a vehicle costing between 35% to 100% more than a conventional one. Thus, governments and policymakers ought to define segmented packs of incentives according to income levels.

This study showed equally that up-front incentives or benefits to decrease the purchase price, like value-added tax exemption and purchase incentives, seem to be the preferred, followed by circulation tax exemption, toll fee discounts, fuel and energy discounts, and loan interests' reduction or exemption. The non-financial benefits were among less selected.

There are two pathways to overcome this issue, both requiring government intervention: making the price accessible by lowering up-front taxes or providing a substantial and easy-to-access financial incentive. Our research findings led us to conclude that families with lower incomes are more responsive to direct discounts rather than paying the purchase price and applying for an incentive afterwards. Loan interests reduction or exemption incentives have been more selected by lower incomes than others, as it allows them to access an expensive technology they cannot afford. However, this latter should not be the solution from a social point of view as it will lead families to excessive debt, further deepening the gap of social differences. Besides, insights from other studies reveal that upper-income

families do not depend on incentives for the purchase decision-making. Therefore, incentive policies must include measures to make AFVs accessible to lower incomes households by reducing the up-front price through a direct rebate on the purchase price (not dependent on concreting the purchase first and then applying for it) or through a lower VAT tax combined with scrappage benefits for older vehicles. These measures would allow attaining the so-called critical mass threshold.

The energy transition and technologies to enable a sustainable energy transition ought to be equitable and take into account socioeconomical differences between households, and more broadly between geographies [39]. However, applying such a policy without positive differentiation is not sustainable from an economic point of view. In this sense, the level of benefits or incentives such as up-front rebates must be inversely proportional to households' income. Although, the authors suggest further research by analysing the respondents' options more in detail to determine consumers' segments by incentive and benefits' packs. Moreover, the authors did not establish a causal relationship between the application of incentive schemes and the increase of willingness to buy, and likewise recommend further research. In addition, for future studies, in order to increase the reliability of the income variable and to reduce eventual bias, the authors suggest to gather individual income instead of households', as some respondent may not have a full knowledge on the total family income.

Although, this paper has been able to identify the missing dots between climate change perception, behaviour, and willingness to purchase AFVs and points out some pathways to handle them, including differentiated incentives packages according to households' income. Nevertheless this study was conducted in only one country (Portugal), the authors believe it provides valuable insights into AFVs incentive policies for other European countries.

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