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Review

Are Existing Battery Electric Vehicles Adoption Studies Able to Inform Policy? A Review for Policymakers

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Abstract: Accelerating the adoption of electric vehicles provides a rare historic opportunity for reducing the dependence on fossil fuel and decarbonising road networks in the field of transport. Many countries have introduced various policy packages on both national and local levels to encourage electric vehicle adoption, but their market shares remain low. For better understanding the reasons behind this evidence, exploring the determinants that influence consumers' adoption intentions is significant. Previous literature reviews have made clear and elaborated syntheses of influential factors; however, a summary of how evidence can be translated into policy through these factors is lacking. In response, this paper synthesises the main policies of various countries, summarises the previous research results, and forms corresponding policy tools, which can provide a reference to policymakers and guide the policy-making process.

Keywords: potential consumers; adoption intentions; electric vehicles; policymakers

1. Introduction

Electric vehicles (EVs) are all types of cars that can be powered partly or fully by electricity [1]. Deployment of electric vehicles is a potential way to decarbonise road networks, and at the same time, may offer wider benefits for the environment such as reducing air pollution [2] and noise [3] in urban areas. Almost every country has by now published its own plans for promoting EV uptake and subsequently provided monetary and non-monetary policies including subsidies and tax exemptions to EV owners and deployed charging infrastructure. Nevertheless, despite these efforts, the market share of EVs all around the world remains low.

At the macrolevel, policy instruments, charging availability and convenience, and governance efforts seem to be essential drivers for EV adoption, and might also be the reasons hindering the process of EV penetration around the world if any of them is lacking. However, a fact that should never be ignored is that EVs are designed to target the mass market. In other words, the opinions and attitudes of potential consumers should be key points in terms of EV penetration.

There have been, by now, many empirical studies from different countries focusing on analysing consumers' adoption intentions for EVs, and also several review papers that provide summaries of the significant factors that might drive EV uptake [1,4,5]. However, previous reviews mainly concentrate on the determinants driving adoption with little attempt to link these findings to the corresponding policy measures. To fill the gap, this study firstly reviews EV related policies across different countries, and then summarises effective policy measures introduced to promote EV adoption from policy evaluation studies in various countries, and finally concludes findings of significant factors and policy suggestions in studies of consumers' EV adoption intentions. The purpose of this review is to provide a summary of effective EV policy implications to policymakers to guide their policy-making process.

This paper is organised as follows. Section 2 lists current government policies that have been introduced across countries and identifies the gaps within countries by the comparison of existing policy measures. Section 3 provides insight into effective measures from empirical policy evaluation studies. Section 4 discusses findings and relevant policy interventions from previous consumer intention studies, and how these can be aligned in the future. Finally, Section 5 concludes the key findings and discusses policy implications.

2. Current Policies to Encourage EV Adoption

According to the data from Global EV outlook 2019 (see, Figure 1) [6], it is clear that both global new EV sales and market shares are increasing. With regard to the performance of each country, in 2018, China achieved the largest number of new EV sales. In terms of EV market share, in the same year, Norway performed best (46%) compared to the rest of the countries, followed by Sweden (c. 8%), Netherlands (c. 7%), and China (c. 4%). Norway, Sweden, and China were the top three countries that had the highest market penetration rates across these countries from 2013 to 2018; Japan showed the slowest increase.

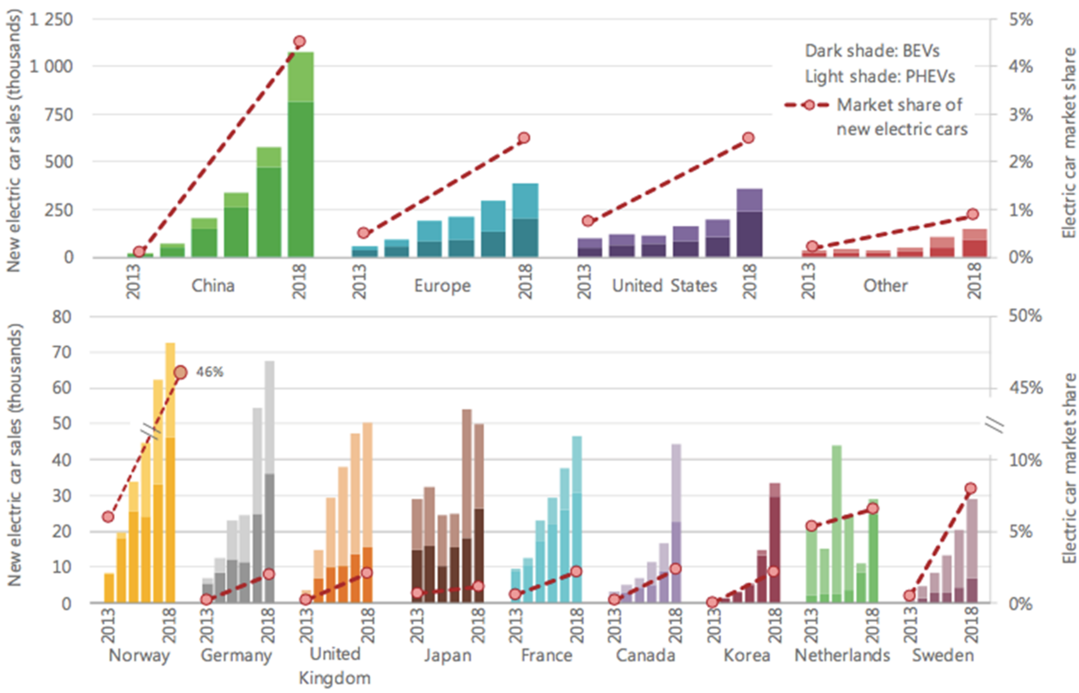

Figure 1. Electric car sales and market share in the top 11 countries and Europe, 2013–2018. SOURCE: Global EV outlook 2019 [6].

A clear message from Figure 1 is that although the global EV market share has been increasing for years, the figures are still low compared to anticipated sales. It is therefore important to have a closer look at policy measures across different countries to examine the evidence behind this phenomenon. Table 1 summarises different policy instruments across the 11 countries shown in Figure 1, collected from various sources [6–18]. We categorised policy measures across different countries into four groups, which are monetary policy incentives, non-monetary incentives, national targets, and regulations. We discuss these categories in the following subsections.

Table 1. Policy measures across countries by the end of 2019.

Policy Incentives		European Union	Norway	Netherlands	Sweden	UK	Germany	France	China	Japan	Korea	Canada	US
Monetary incentives	Tax benefits		Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green
	Purchase subsidies				Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Light green
	Charging subsidies		Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Light green	Dark green	Dark green	Dark green	Dark green
	Industrial subsidies								Dark green	Dark green	Dark green	Dark green	
	Free tolls, parking, ferries		Dark green			Dark green	Dark green	Light green	Light green	Light green	Dark green	Light green	
Non-monetary incentives	Travel priority		Dark green	Light green	Light green	Light green	Light green	Light green	Light green			Light green	Light green
	Parking priority		Dark green		Light green	Dark green	Light green	Dark green					
Target	Target for vehicles		Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Light green
	Target for chargers	Dark green		Light green			Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Light green
Regulations	ZEV mandate								Dark green			Light green	Light green
	Fuel economy standards	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green
	Buildings	Dark green	Light green						Light green			Light green	Light green
	Public procurement	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green	Dark green		Dark green		

SOURCE: IEA, policy database [7]; International Energy Agency (2019) [6]; Norsk elbilforening (2020) [11]; BALZHÄUSER (2019) [12]; Office for Low Emission Vehicles (2016) [13]; European Commission (2019) [14]; Columbia University (2020) [15]; Ministry of Finance of the People's Republic of China (2020) [16]; Hybrid & Electric Vehicle Technology Collaboration Programme (2012) [17]; Balzer (2020) [18]; International Energy Agency (2016) [8]; International Energy Agency (2017) [9]; International Energy Agency (2018) [10]. Notes: Dark green means national policies, light green means local policies.

2.1. Monetary Incentives

Monetary incentives are important measures to reduce the price gap between EVs and conventional vehicles. They are directly associated with consumers, industry, and infrastructure. By synthesising published policy measures, we classified this group into three parts: tax incentives (reduction or exemption of purchase/operation/VAT tax); monetary subsidies for vehicles (purchase subsidies); charging infrastructure and industry; other monetary benefits such as reduced or free tolls; free parking and free transfers on ferries.

As shown in Table 1, the top 11 countries in terms of EV market share have introduced their own tax incentives. Most countries (Norway [11], UK [13], China [16], Korea [6], and Germany [17]) offer a direct reduction or complete tax exemption to EV owners. Sweden deployed a more strict bonus–penalty taxation system according to the fuel economy standards in 2018 [7]. Bonuses would be given to EV users while increased vehicle taxes would target petrol and diesel car owners. This kind of taxation system can not only promote EV uptake but would also contribute to a reduction of the demand for internal combustion engine (ICE) vehicles.

Subsidies for the deployment of private and public charging infrastructure is a step that every country has taken. Additionally, providing purchase subsidies to consumers is also a popular policy measure. For example, the UK government [13] has released the Plug-in Car Grant which enables EV owners to save up to 35% of the cost of an EV (up to a maximum of £4,500 according to the model) and 20% of the cost of an electric van (up to a maximum of £8000). Other grant programmes including the Electric Vehicle Home Charge Scheme (EVHS), Workplace Charge Point Scheme (WCS), On-Street Residential Charge Point Scheme (ORCS) provide £80m for improving the EV charging infrastructure [13].

Compared to subsidies in the above two parts, the measure of providing subsidies to the industry (EV manufacturers and battery manufacturers) lacks in most countries. According to Table 1, only China, Japan, Korea, and Canada have published clear financial investment schemes for the industry. EVs are crucially positioned as a potential enabler of major cost reductions in battery technology, one of the key value chains of strategic importance for industrial competitiveness, given its relevance to the clean energy transition. For example [6], Japan and Korea have ambitions to enlarge their EV market with the target of increasing zero-emission cars tenfold by 2022. To achieve this target, car manufactures will receive financial support from the governments for research and development (R&D) of battery innovations.

As for other kinds of monetary benefits such as free tolls, parking, and ferry access for EVs, these are usually deployed both at the national level and local level. This indicates the flexibility of policymaking for local governments.

2.2. Non-Monetary Incentives

Financial incentives are particularly essential while the purchase price of EVs remains higher than ICEs. However, when the price battery reduces as the technology matures, more value would be put on non-monetary incentives [10]. In general, non-monetary incentives include travel and parking priority. Travel priority can embody access privileges, such as permit to drive on HOV/bus lanes and exemption from traffic restrictions. For example, London has declared that EVs and plug-in hybrid electric vehicles (PHEVs) are exempt from London's Congestion Charge scheme until 2025 [12]. China is another country that has been steering this measure for a long time. In some cities in China, including Beijing and Shanghai, EV users can get their vehicle license plates cheaper and faster. EVs are also exempt from traffic restrictions of certain days based on license plate numbers [7]. Table 1 shows that most of these added value policy measures are made on the local level.

2.3. National Targets

Targets play an important role in accelerating EV penetration, as they can help shift the focus of discussion to increasing the EV market share and improving charging infrastructure. These targets are usually made subsequently with relatively mature policy packages by the governments, thus they can be seen as an opportunity for new development. Table 1 shows that all countries have their own targets for number of EVs and market shares. However, the light colour for the US suggests that their targets are based on the local level as only California and eight other states have announced a targeted number of EVs [6]. This reflects the imbalanced deployment of local policy measures even within one country.

2.4. Mandates and Regulations

Mandates and regulations refer to government requirements for manufacturers and consumers. These policy instruments usually have regulatory power. Table 1 categorises them into zero-emission vehicle (ZEV) mandates, fuel economy regulations, ban of ICE manufacturing, regulations for buildings to adapt chargers, and public procurement. Table 1 also presents that to date, only China, the state of California (US), and the province of Quebec (Canada) have introduced zero-emission vehicle (ZEV) mandates for manufacturers [6]. China initiated ZEV mandates in 2016 and has regulated manufacturers to produce certain numbers of EVs to get the required credits. If some manufacturers have more production capacity and earn excessive credit, they can trade with other manufacturers who are unable to meet the annual minimum requirements of credits. The target of this mandate is to achieve 12% New Energy Vehicle (NEV) credit sales in passenger cars by 2020 [19]. The ZEV mandate is a strong driver for manufacturers to improve their EV production capacity and optimise resource allocation through credit trading.

All countries shown in Table 1 have also developed fuel economy regulations. These regulations can help boost the adoption of sustainable and energy-efficient technologies. Policy measures such as a differential taxation system between conventional cars and EVs, and ZEV mandates are designed and deployed based on the fuel economy standards. Thus, it suggests that the improvement of ICE and hybrid fuel economy standards would be a strong driver for the transition to EVs.

Another kind of regulation is the charging infrastructure regulation on buildings. As Table 1 shows, this policy measure is usually developed at a local level, and only some local authorities in Canada, the US, and Norway have implemented such regulations. Also, the European Union published the Energy Performance of Buildings Directive in 2019, which sets minimum requirements for charging infrastructure in new and renovated buildings.

The policy for public procurement of EVs is that all the government fleets, bus fleets, and dedicated fleets (police fleets, solid waste collection vehicles) that are subject to public procurement should adopt EVs [9]. The European Commission launched the Clean Vehicle Directive [14], which mandates country members to participate in EV public procurement. Table 1 shows that the majority of the countries have implemented this public procurement regulation.

Through observation and comparison of these policy instruments, current policy measures and relevant suggestions for policymakers are:

- Subsidies to the industry for battery innovation seem to be insufficient in most countries. Policymakers should think carefully about how to promote the R&D of battery technology and organize a life-cycle supply chain in the industrial context.
- Most non-monetary policies, such as travel priority (access to bus/HOV lanes, exemption from traffic restrictions) and parking priority are designed and deployed on the local level rather than the national level. Therefore, non-monetary policy measures should be implemented with more flexibility based on the specific local context.
- Monetary incentives are important to close the gap between the purchase price of EVs and ICEs and increase adoption rates. However, the importance of non-monetary incentives should not be

ignored by policymakers as they may be more effective in the long term when price is not a major barrier to EV adoption.

- Governance awareness on promoting EV adoption and funding to support local policy measures could be imbalanced within the same country. This may lead to certain areas standing out in terms of offering effective EV policy interventions compared to other regions. Therefore, national targets for EVs and charging infrastructure should be set to guide local governments, and funding from the central government should also be allocated reasonably across regions.
- Fuel economy regulation is an efficient way to help design a taxation system for motor vehicles and ZEV mandates for EV manufacturers.
- Regulations on buildings to meet EV charging requirements and the regulation of public procurement both enable the roll-out of EVs and chargers to potential consumers, which may attract wider adoption.

The above findings emerging from Table 1 are based on the classification and comparison of existing EV policy measures in different countries. Further summaries of testing with different policy packages are necessary.

3. Empirical Studies on Potential Acceptance of Policy Measures to Encourage EV Adoption

Section 2 identified potential gaps in current policy measures across countries, however, whether these measures are effective in practice needs to be further explored. Table 2 summarises findings from empirical studies focusing on the public acceptance of EV policy measures.

Table 2. An overview of effective policy measures for promoting EV adoption in different countries.

Author/Year	Country	Research Focus	Effective Policy Measures
		Effective Policy Measures in Different Countries	
Kester et al., 2018 [20]	Nordic countries	Qualitative analysis of policy effectiveness	Cost reduction mechanisms (taxation exemption) Charging infrastructure for public Consumer awareness (information campaigns) Procurement Environmental zones
Olson 2018 [21]	Norway, California	Relative importance of technology improvements and EV supporting public policies	EV supporting public policies (motivate early adoption) Technical deficiencies & high prices (hinder EV penetration)
Wang et al., 2017 [22]	China	EV adoption intentions	Financial policies Information provision policies Convenience policies * (exemption from travel restrictions and parking priority)
Zhang et al., 2018 [23]	China (Beijing)	Stated preferences towards EVs	License plate lottery * Purchase subsidies
		Effective Paradigms of Policy Measures	
Held and Gerrits, 2019 [24]	15 European cities	Configuration that is sufficient for the favourable outcome	Cost reduction measures + charging infrastructure construction + public charging grid design + ICE restriction
Rietmann and Lieven, 2019 [25]	20 countries	The effectiveness of policy measures and a prediction of future growth trends	Monetary measures + charging infrastructure
Nie et al., 2016 [26]	Hypothetical case study	Optimal design of subsidy by using mathematical models	Investment priority on building charging stations compared to purchase subsidies

Table 2. *Cont.*

Author/Year	Country	Research Focus	Effective Policy Measures
		Effective Policy Measures over Time	
Li et al., 2019 [27]	China	Dynamic impacts of government policies	Short term: appropriate fuel vehicle license plate restriction + gradually reduced consumer purchase subsidy Middle term: gradually decreased manufacturer subsidy + reduced parking fees and road maintenance fees + standardised charging facilities Long term: improve smart grid infrastructure + start vehicle-to-grid Whole period: perfect carbon tax policy + develop EV core technologies
Benvenutti et al., 2017 [28]	Brazil	Impact of public policies on the long-term diffusion dynamics of AFV	Short term: tax policies for consumers and manufacturers Long term: banning regulation
Skjølsvold and Ryghaug, 2019 [29]	Norway	Norwegian EV transition from a socio-technical perspective	Interactive effects of policy measures across countries
Rietmann and Lieven, 2019 [25]	20 countries	The effectiveness of policy measures and a prediction of future growth trends	Policies respond to the preference of adopting BEVs more than PHEVs
Kangur et al., 2017 [30]	Netherland	How policies interact with consumer behaviour over time	A combination of monetary, structural and informational measures Support to BEVs, not hybrid vehicles
Neves et al., 2019 [31]	24 EU countries	Factors supporting the transition to EVs over time	Technology progress Provision charging stations Policies tailored individually for BEV and PHEV
Zhu et al., 2019 [32]	China	Indirect network effects between EV sales and charging infrastructure constructions under the phasing out subsidy situation	Indirect network effects: subsidy from consumers to charging infrastructure Integration of EVs with clean electricity production Increase in gasoline price

Notes: * indicates effective local policy measures.

3.1. Effective National and Local Policy Measures

The results of Table 2 confirm that policy measures are diverse across different geographic areas. Olson [21] examines the case of the lead market for EVs—Norway and California. The results suggest that EV related public policies are the most powerful incentives for early adoption, while technical deficiencies and costly purchase price remain major barriers to wider EV uptake. However, Kester et al. [20] argue that the integration of powerful and stable national targets, purchase subsidies, and local policy measures (zone access restriction), public procurement, and information campaigns for arousing consumer awareness enable the further promotion of EV penetration in Nordic countries.

In China, Wang et al. [22] found that financial incentives, information provision about EVs, and convenience measures all have positive effects on consumer EV adoption intentions. Within all these three policies, convenience measures such as exemption from travel restrictions and parking priority were the most efficient ones. Analysis of local licence plate control measures in China confirmed that both local measures (exemption from plate lottery) and national measures (purchase subsidies) were highly associated with the increased EV market share in Beijing [23]. Held and Gerrits [24] also emphasised the importance of integrating national and local policy measures to enable further EV uptake. These studies indicate that local policy interventions also played an important role in promoting EV adoption.

Effective policy measures in different countries vary according to their own contexts, however, some studies are interested in finding commonly applicable policy formulae for promoting EV adoption. These studies suggest that it is not wise to count on one powerful policy to make a difference in the EV penetration process [24,26], instead all promising measures should be integrated. Through a Qualitative Comparative Analysis (QCA) of both local and national EV policies across 15 European cities, Held and Gerrits [24] recommended a paradigm to promote EV adoption—lower total cost, private/public charger installation, and ICE restrictions. This was in line with Rietmann and Lieven [25] who analysed EV policy measures across 20 countries and found that monetary measures, national purchasing power, traffic regulations, and charging infrastructure had positive effects on EV adoption; in particular, monetary measures along with the charging infrastructure construction were the most important. Nie et al. [26] believe that the optimal design of subsidy measures is to invest in charging stations in the first place, rather than the current preference of providing monetary incentives to consumers.

3.2. Effective Policy Measures over Time

It is essential for policymakers to know what the significant policy measures are and what is the formula or effective combination for encouraging future EV adoption. However, all studies mentioned above only focus on policy interventions at a specific or fixed time. Therefore, how the impacts of policy measures evolve with time should be explored in the future.

The results of the study from Li et al. [27] showed that an increasing number of manufacturers in the network, tax and subsidy policies for consumers and manufacturers, and fuel vehicle license plate restrictions could realise full EV diffusion. However, the work of Kangur et al. [30] suggested that effective policy would require a long-lasting implementation of a combination of monetary, structural (e.g., installation of charging infrastructure), and information campaign measures. Li et al. [27] suggested that the production subsidies for manufacturers were more influential compared to consumer purchase subsidies. Zhu et al. [32] confirmed indirect network effects between EV sales and EV charging infrastructure construction and suggested that governments should shift from purchase subsidies to charging infrastructure subsidies while phasing out EV subsidies.

In terms of the EV market in China, Li et al. [27] provided recommendations on the design of future policy measures at different stages. In the short term (2018–2020), the focus of the measures should be implementing appropriate fuel vehicle license plate restriction and gradual reduction of consumer purchase subsidies. In the midterm (2021–2025), the focus should be put on the gradual decrease of manufacturer subsidies, reduction of parking fees and road maintenance fees, and standardisation of charging facilities. In the long term (2026–2030) measures for improving smart grid infrastructure and implementing vehicle-to-grid (V2G) technologies should be stressed. Meanwhile, setting and perfecting carbon tax policies and accelerating the development of EV core technologies should remain targets during the whole period [27]. Benvenutti et al. [28] suggested that current tax and subsidy incentive policies are important to achieve the short term target of Alternative Fuel Vehicles (AFV), but the banning of ICEs could take effect in the long term (by 2060).

The evidence from a study by Rietmann and Lieven [25] across 20 countries shows that consumers tend to purchase more BEVs (vs. PHEVs) over time according to sales data. Kangur et al. [30] also suggested that the strongest effect on emission reduction requires exclusive support for full battery-electric cars, but not hybrid cars. Neves et al. [31] put the focus on policy measures on Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) from a panel data of 24 EU countries between 2010 and 2016. Their findings showed that the factors supporting BEVs were quite different from those driving PHEV adoption, which indicates that policies should be tailored to individual technologies, rather than a single one for all EVs.

Policies within each country are not independent of other countries, Skjølsvold and Ryghaug [29] argued that policies across borders could have interactive effects and defined this phenomenon as "temporal echoes". They argued that California's ZEV legislation in 1990 had a direct influence on the early EV market in Norway. Also, Zhu et al. [32] suggested that EV promotion should be integrated with clean electricity generation and gasoline price which has positive effects for EV adoption over time.

Section 3 synthesised policy measures related to EV adoption across different countries (see Table 3). The trends of these measures and corresponding suggestions for policymakers are as follows:

- Previous studies can be divided into static and dynamic analyses. Static studies focus on the cross-sectional analysis of policy instruments at a specific or fixed time, while dynamic analysis presents the impacts of policies using panel data.
- Effective measures are diverse across different geographic areas, but monetary incentives are significant in all cases. Similarly, the effective formulas for wider EV adoption diversify in different studies, but they all stress the importance of monetary measures and charging infrastructure construction.
- Local policy measures are equally important as national measures. The reason why some local governments stand out at developing successful measures relates to the attitudes of local governments towards clean energy [33]. This finding suggests that the endeavours of local governments are to strengthen their environmental awareness.
- Evidence from California and Norway shows that policies deployed in different countries are not completely independent, they can interact and spark new initiatives. This finding highlights the capacity of some governments to act fast and localise good external policies when this exchange of new policy takes place.
- By observing the dynamic analysis of significant policy measures, monetary incentives are very effective in the short term. However, as the technology develops, the cost of EVs is expected to decrease and the price gap between EVs and ICEs would be minimal. Then the government subsidy process should shift from consumers to manufacturers. In the long term, the focus of governments should be on the integration of EVs and the electricity grid to help achieve more sustainable targets both in the transport and energy industries.
- Over time, the market has had a tendency to transition from PHEVs to BEVs. Therefore, policy measures that target BEVs are more important in the future. Meanwhile, more specific policies should be tailored to different kinds of EVs, as the policy incentives for these two types of cars are different.

4. Future Policy Interventions Driven by Consumer Adoption Intention Studies

Table 3 summarises the factors associated with EV adoption intention as these were documented in studies published over the last five years [31,34–45]. These factors include vehicle price, vehicle usage, social networks, personal norms, environmental awareness, pro-technology attitudes, monetary incentives, consumer cognitive status, product perception, driving emotions, marketing, V2G capability, and socio-economic characteristics.

Table 3. Significant factors and suggestions for policy interventions in EV adoption intention studies.

Significant Factors for EV Adoption Intentions		Suggestions for Policy Interventions
Perceived behavioural control	Vehicle price, vehicle usage [38]	• Sustain monetary policy measures to reduce vehicle total cost. • Support the improvement of EVs on a technical level and in quality reliability (driving range, battery life). • Provide more support to car manufacturers and R&D in the market.
	Driving range, battery life [44]	
Subjective norm	Social networks [42]	• Facilitate social activities. • Make EVs more visible to the mass market (neighbourhood effects and public procurement).
Attitudes	Environmental awareness [35,41,44]	• Support the "green" or "high-tech" image publicity campaigns of EVs.
	Pro-innovation [35]	
	Personal norms (individual beliefs) [37]	• Carefully make specific policies that target potential consumers with different personal traits/beliefs.
Emotions	Driving emotions [37]	• Support manufacturers in improving the functional/instrumental aspects of EVs.
External factors	Monetary incentive policy [39,40]	• Continue implementing monetary policy measures.
	V2G capability [34]	• Start to evaluate the economic and social viability of the V2G system.
	Consumer cognitive status [40]	• Improve consumers cognition of EVs and policies by supporting information publicity and trials in the market.
	Marketing [44]	• Supervise after-sales service quality and various purchase channels. • Support diverse brands as well as advertising campaigns in the market.
Socio-economic characteristics	Age, gender, income, education level, number of children, household size, people with similar attitudes towards EVs live closer, do not own a car	• Carefully make specific policies that target potential consumers with different socio-economic characteristics. • Use neighbourhood effects to promote EV transition. • Design and evaluate new business models: e-car sharing, e-hailing, or peer-to-peer e-car rental and lease.

4.1. *Perceived Behavioural Control*

Perceived behavioural control refers to the perceived ease or difficulty for individuals to perform a certain behaviour successfully [46]. Previous studies [37–40,43] have already provided evidence on the significance of people's perceived behavioural control on EV adoption intentions. Empirical analyses confirm that vehicle price, aspects related to vehicle usage (e.g., running cost, charging availability and time), driving range, and battery life are all significant factors for consumers.

Berkeley et al. [43] identified "economic uncertainty" and "socio-technical" factors as determinants for EV adoption through the exploratory factor analysis of perceived barriers to EVs from a survey of 26,000 motorists in the UK. "Economic uncertainty" refers to the following barriers: high purchase price of EVs, long waits for fuel and taxation outweighed high purchase price, anxiety over the re-sale value, maintenance uncertainty, and lack of choice of EVs in the market. On the other hand, "socio-technical" barriers include the availability of public charging, charging time, driving range limitation, concerns about behaviour adaptiveness, and complexity of the charging process. Zhuge and Shao [38] also reported that vehicle price and usage measured as user satisfaction on the daily use of their car (running cost, charging availability and time, driving range), were the two most influential factors driving consumer concerns about EVs.

In some cases, people's perceived behavioural control towards EVs was the most influential factor [38,39]. Thus, the response of policy measures to consumers' perceived difficulties in terms of the high purchase price, charging infrastructure, range, battery life could direct monetary incentives to reduce vehicle total cost and improve charging infrastructure, vehicle range, and battery life. This finding suggests that EV quality on a technical level is not only vital, but governments should also put more attention and effort towards supporting car manufacturers and R&D in the industry.

4.2. Subjective Norms

Subjective norms refer to the effects social networks have on individuals' opinions on choosing whether to exhibit a certain behaviour [46]. Empirical studies stress that subjective norms are significant to consumers' EV adoption intentions [39,42].

The evidence from Habich-Sobiegalla et al. [42] suggests that a large social network is the most powerful factor for EV purchase intentions in China. Similar findings were also confirmed in Malaysia [36], which showed that consumers' EV purchase intentions were influenced by their social norms, rather than personal norms/beliefs. Also, Mohamed et al. [37] showed that the specific notion of "made in Canada" vehicle adoption was deeply embedded in people's minds based on individual moral obligation to buy locally.

The positive influence of others and the societal norms regarding EV purchase intentions could be enhanced through wider social networks [36,37,39,41,42,47]. Thus, policy measures such as publicity on social platforms and encouraging consumers to widen their social networks might be effective in response to this influence. Some measures that governments could implement are thinking about ways to reduce people's social distance physically and let EVs become more visible to the mass market, for example, through public procurement. In these ways, higher adoption rates might be achieved through visible EV images and interactive communications between friends, family members, neighbours, and co-workers [48].

4.3. Attitudes

Attitudes refer to people's positive or negative evaluations of a certain behaviour [46]. A positive evaluation of a specific behaviour is similar to the concept of perceived benefits, while a negative rating is similar to perceived barriers. There are relevant studies confirming that people's attitudes towards EVs are significant to their adoption intentions [36,37,39].

Mohamed et al. [37] showed that consumers' environmental awareness in Canada had an indirect impact on adoption intentions. Priessner et al. [45] reported on a case study in Austria and found that that environmental awareness and personal worldviews/norms/beliefs were the most influential factors for people's willingness to purchase EVs. Simsekoglu and Nayum [41] found that environmental-economic attributes had positive impacts on consumer EV adoption intentions in Norway. For potential adopters of EVs in Danes' view, the green symbolism of these cars was the most important factor for them in making their choices [47].

Therefore, policymakers' main efforts should be put into implement publicity measures to improve the "green" image and "high-tech" perception of EVs [35]. It is also important to target potential consumers carefully to ensure policy measures meet individual traits/beliefs.

4.4. Emotions

During the consideration of EV adoption, other than the rational evaluation of all the factors related to EVs, there is evidence from empirical cases suggesting that emotions related to driving EVs were also an important concern for adoption [47,49].

Moons and De Pelsmacker [49] found that visceral emotions (feelings triggered by instrumental attributes) such as exterior style, size and design; behavioural emotions (feelings during daily experience and operation); and reflective emotions (feelings aroused by symbolic meanings behind using EVs) are significant for EV adoption intentions.

In response, policy measures related to this factor are suggested to emphasise the improvements in infrastructure and driving range. In this way, the perception that functional restrictions outweigh the positive driving experience can be avoided [47].

4.5. External Factors: Monetary Policies, Marketing, V2G Availability

External factors such as government policies, marketing campaigns, consumer cognitive status of EVs, and the availability of vehicle-to-grid (V2G) integration systems were found to be important for EV adoption intentions [34,39,44].

Chen et al. [34] suggested that V2G capability could be the "tipping point" for future EV uptake in Nordic countries. The authors suggested that the emphasis of governments in these countries should be on V2G capability rather than blindly investing in installing public chargers. The authors also argued that a V2G system would be more cost-effective in the long term as it would prevent the further waste of investment in grid development, and would provide wider benefits for both the energy system and transport system [34]. Wang et al. [44] showed that marketing was the most significant factor associated with the acceptance of EVs. Two case studies in China also confirmed that monetary policy measures were significant, but non-monetary policies were not very effective for supporting consumer adoption intentions [39,40]. Consumer cognitive status [40], which usually refers to consumer knowledge about the product, has also been proven significant for EV adoption.

Therefore, policies corresponding to external factors should be taken into consideration. For example, governments should continue to implement monetary policy measures and start to think whether it is viable economically and socially to provide a V2G system and improve consumer cognition of EVs and policies through information publicity and trials. As for the governmental role in ensuring EV marketing, measures should include supervisions on after-sales service quality and various purchase channels as well as support for diversity of brands and advertising campaigns in the market.

4.6. Individual Characteristics

Socio-economic characteristics of people who stated willingness to purchase EVs not only exhibit geographic differences but also some common traits (see Table A1).

The evidence on the influences of gender on EV adoption intentions is mixed. There have been studies indicating that males tended to show a higher interest in EV adoption [34,36,44,45,47]. Berkeley et al. [43] argued that women may perceive EVs to be unreliable and unable to meet their needs when taking children to school. On the other hand, evidence in China shows no gender differences regarding individuals' stated interests for EVs, whereas there were significant differences in the reasons for adopting an EV between women and men [40]. Males focused more on EV performance, while females paid more attention to the economic incentives. By contrast, a study by Simsekoglu and Nayum [41] found that males were negative in terms of EV adoption. This can be interpreted as women having a weaker habit of conventional car use compared to men [50].

With regard to potential users' age, there are also mixed findings in previous works. Chen et al. [34] and Huang and Ge [40] showed that younger individuals were more likely to purchase EVs. Huang and Ge [40] explained that younger individuals were more open to and interested in new products. On the other hand, Habich-Sobiegalla et al. [42] and Adnan et al. [36] indicated that older individuals were more likely to purchase EVs, which may be related to affordability and higher economic certainty compared to the younger individuals who usually depend on leasing [43]. To further examine the influence of age, Wang et al. [44] found that individuals aged between 18 and 25 years were more likely to adopt EVs as their second cars, while those aged 41 to 50 years were more likely to buy EVs to replace their conventional vehicles.

According to the findings summarised above, further study of gender differences on consumers' attitudes towards EVs should be conducted as a potential research direction, and corresponding policies should be made to better motivate the market. Work to identify groups with different socio-economic characteristics and psychological preferences should also be conducted to enable improved targeting of potential groups of adopters.

Despite mixed findings regarding gender and age, there are also common patterns. In summary, individuals with higher income [34,36,38,40,42,44], higher level of education qualifications [36,38,40,47], larger household size [45], and number of children [34] were more likely to adopt an EV. A study by Zhuge and Shao [38] also suggested that people who had similar attitudes towards vehicle use and purchase restrictions of EVs lived close to each other. This finding also points to the importance of neighbourhood effects. In terms of car ownership, Huang and Ge [40] and Priessner et al. [45] found that people who expressed higher interests in EV adoption usually did not have a car. This characteristic highlights the need to further think and develop new EV business models, such as e-car sharing, e-hailing, or peer-to-peer e-car rental and lease. In these visions, people do not need to own an EV for achieving future EV penetration, however, the environmental benefits would keep existing as long as a continuous transition to higher EV use occurs [45].

5. Conclusions

This paper contributes to the body of knowledge concerning the improvement of the sustainability of transport systems by decarbonising road transport networks and taking policy measures towards wider EV penetration.

Through a targeted literature review we consolidated knowledge and empirical evidence across three areas. Firstly, we presented the state of action regarding government initiatives to encourage the adoption of EVs by reviewing policy initiatives of countries within the top 11 of the EV market share. One of our key findings was that subsidies towards car manufacturers should be extended further across countries (e.g., Norway, Netherlands, Sweden, UK, Germany, France, and USA) in conjunction with local-area incentives (e.g., travel and parking priority).

Secondly, we discussed the state of effective policy interventions as these emerged from reviewing empirical studies across different countries. These studies were categorised into two types: static and dynamic. Both types of studies confirmed that significant measures were diverse across different geographic areas, but the monetary incentives were significant in all cases [20–23]. Local-area incentives held equal importance as national-level incentives [22,23]. Formulas for successful EV transitions in static analyses recognised the importance of monetary incentives and the installation of charging infrastructure [24,25]. With regard to dynamic analyses, findings showed that subsidy incentives would gradually shift from consumers to manufacturers in the short term and then onto the grid system (e.g., to enable smart grid and V2G) in the long term [27]. Furthermore, the transition from PHEVs to BEVs would become higher over time [25]. Policies can interact with each other across geographic areas and time [29]. When designing policies, measures should be clearly distinguished between PHEVs to BEVs, and more focus should be put on BEVs over time with the predicted trend of a higher adoption rate for BEVs in the future according to sales data [25].

Finally, we presented the state of knowledge regarding intentions to adopt EVs from a consumer perspective and consolidated individual characteristics that may result in different profiles of car buyers more likely to adopt an EV. For example, consumers' pro-environment, pro-innovation, and symbolic attitudes towards EVs motivate their adoption intentions. Other factors also played a significant role in influencing consumer intentions towards EV adoption, such as perceived behavioural control (e.g., vehicle price, vehicle usage, driving range, battery life), subjective norms (e.g., social networks), emotions and external factors (e.g., monetary incentive policies, V2G capability, consumer cognitive status).

Governments have a leading role to play towards wider EV adoption, that is the origin of public procurement, which can not only widen EV penetration but also present EV use images to the public. Regarding the automotive industry, car and battery manufacturers need to conduct research and development to improve the driving range of cars, work towards new battery technologies to reduce the cost of batteries, and develop battery recycling facilities. Charging management companies need to design reliable charging strategies to attract consumers with the development of smart charging technology. As for car sale companies, various marketing techniques should be designed and promoted to attract potential consumers, such as developing EV trials, improving after-sales service quality, and introducing various purchase channels [44]. Publicity campaigns are another good way to enhance the "green" or "high tech" image of EVs to target early adopters.

One limitation is that we have only reviewed papers in English, but a lot of organisations and individuals now publish their policy documents and research findings in English. Future research should extend to the influence of local policy measures, and how it interacts with national policy interventions. Significant contributions should also emerge when aiming at the importance of good governance for exploring models of coordination across stakeholders and developing a stable and sustainable supply chain.

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Appendix A

Table A1. Significant factors in EV adoption intention (studies over the last five years).

Author/Year	Sample Size	EV Adoption Intention Measurement	Significant Factors	Methodology	Socio-Economic Characteristics Stated with EV Adoption Intention
Chen et al. (2020) [34]	4885 survey respondents, Denmark, Finland, Iceland, Norway, Sweden	Potential EV adoption	Fuel economy Financial savings Environmental value V2G capability Charging time	Hierarchical regression analysis	Younger males Higher income Higher number of children Have previous EV experiences Hold sustainability values
Zhuge and Shao (2019) [38]	Beijing, China	EV purchase intention	Vehicle price (1) Vehicle usage (2) Social network (3) Environmental awareness (4) Purchase restriction (5) Traffic restriction (6)	Clustering analysis; Multinomial Logit (MNL) models; Moran's I;	Higher income Higher education level People who have similar attitudes towards vehicle usage and purchase restrictions tend to live close to each other
Xu et al. (2019) [39]	382 respondents, Zhejiang province, China	Customers' purchase intention of BEVs	Perceived behavioural control (1) Subjective norm (2) Environmental performance (3) Attitude (4) Monetary incentive policy (5)	Structural equation model (SEM); Neural network (NN);	Not mentioned
Huang and Ge (2019) [40]	502 survey, Beijing, China	EV purchasing intention	Consumer cognitive status Product perception Attitude Perceived behavioural control Monetary incentive policy measures	structural equation model (SEM);	Younger group Group without cars High income High level of education Male group (focus on EV performance) Female group (focus on economic incentives)
Simsekoglu and Nayum (2019) [41]	205 conventional car drivers, Norway	Intention to buy a BEV	Perceived behavioural control (1) Subjective norm (2) Environmental-economic attributes (3)	Regression analysis;	Being male negatively related to the intention
Habich-Sobiegalla et al. (2019) [42]	1080 respondents, China	EV purchase intention	Social network	Ordered logistic regression	Older groups Higher income groups
Haustein and Jensen (2018)	CV users (1794), Sweden and Demark	EV adoption intention	Symbolic attitudes (1) Perceived behavioural control (2) Affective attitudes of driving pleasure and excitement (3) Subjective norm (4) Personal norm (5)	Regression models	Male People with university education

Table A1. *Cont.*

Author/Year	Sample Size	EV Adoption Intention Measurement	Significant Factors	Methodology	Socio-Economic Characteristics Stated with EV Adoption Intention
Berkeley et al. (2018) [43]	26,000 motorists, UK	Perceived barriers to EV adoption	Economic uncertainty Socio-technical	Exploratory factor analysis	Not mentioned
Wang et al. (2018) [44]	458 respondents, Shanghai, China	EV public acceptance	Marketing (1, −) Technical level (2, +) Environmental awareness (3, +) Perceived risks (4, −)	Factor analysis; Structural equation model;	Intention to buy EVs as the second car: Male Age of 18 to 25 years old Educational level of junior middle school or lower Household income < 50,000 yuan and 200,000 < household income < 300,000 yuan Intention to buy EVs to replace the CVs: 41–50 years old 300,000 < household income < 500,000 yuan
Priessner et al. (2018) [45]	1000 respondents, Austria	Willingness to purchase EVs	Pro-environmental attitude Individualistic worldview	Multinomial logistic regression (MLR)	Do not own or regularly need a car Bigger household size Male
Egbue et al. (2017) [35]	157 responses of a Facebook survey	EV adoption intention	Pro-innovation attitude Pro-environment attitude Distance driven EV speed perception	Logistic regression	Not mentioned
Adnan et al. (2017b) [36]	391 respondents, Malaysia	Customer's EV purchase intention	Environmental concern Social norm	Partial least square (PLS); Structural equation Modelling (SEM);	Male Older groups Higher income Higher level of education
Mohamed et al. (2016) [37]	3505 households, Canada	Intention to adopt EV	Environmental concern (indirect) Subjective norm Perceived behavioural controlAttitude	Structural equation modelling (SEM); Two-Step cluster analysis;	Typical early adopters (45%): Young to middle-aged, well educated, working, growing families, financial capability to afford an EV, high proportion of single detached dwellings and availability of garage, live in predominately suburban areas with some non-metropolitan members Emerging early adopters (28.2%): Highly educated, small families, more urban oriented with a high peak in condo and apartment dwellings, interested in EV as a future purchase in 3-5 years Interested retirees (26.6%): Small families, interested in a replacement vehicle, annual travelled distance is shorter

Notes: The numbers (1,2,3,4...) in the brackets indicate the ranking of importance of factors, "+" indicates significant positive effects, "−" indicates significant negative effects.

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