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"Policy options for the promotion of electric vehicles: a review"

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Abstract

The upward trend in fuel prices and the desire to reduce pollution levels mean that the electric vehicle has become an increasingly attractive alternative in recent years. The aim of this study is to examine the main barriers that the electric vehicle must overcome if it is to become a successful mode of transport and to review the main public policies that governments might implement to help in overcoming these obstacles. Public policies have been directed at four basic features of the electric vehicle: the charging network; increasing demand for these vehicles; industrialization and research and development programs; and the introduction of electric vehicles in programs of sustainable mobility. This article describes the public policies that have been implemented around the world to overcome the barriers to the adoption of electric vehicle so that it might become the vehicle of the future.

JEL classification: H23; P28; Q42.
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1. Introduction

Although electric vehicles have experienced increasing popularity in recent years, their history can in fact be traced back many years. The first electric vehicle was built in 1834 and by the early 1890s electric vehicles were on sale as one of the main competitors to the internal combustion engine (hereafter ICE), capturing more than a third of the market (Kley et al, 2011). However, ICE vehicles managed to impose themselves owing to their lower costs, both in terms of vehicle production and the price of petroleum fuel, while electric vehicles were handicapped by a travel range that was dependent on battery life.

However, rising oil prices[1], the reduction in the cost and the increased autonomy of electric batteries, and increasing concern regarding the emission of greenhouse gases in developed economies[2], have combined to raise interest in the potential of electric vehicles.

Thus, once again the electric vehicle has emerged as a serious competitor to the ICE vehicle. The electric vehicle offers many advantages, which can be summed up in its overall greater energy efficiency. This perhaps is the primary motive prompting public authorities to implement a package of measures to help introduce the electric vehicle at a range of levels (state, regional and local).

These measures resort not only to the traditional instrument of the subsidy for the purchase of electric vehicles, as applied to hybrid or "green" ICE vehicles in countries such as the United States, Germany, the United Kingdom and Spain[3], but also to other measures that tackle the "chicken or the egg" dilemma: there are no electric cars because there are no recharging points and there are no charging points because there are no electric vehicles. Thus, additional measures have been designed by the

[1] Prices of Brent crude oil (taking into account inflation) increased from 23.95 dollars in 1973 to 102.61 dollars in 1979 (an increase of 428.4 percent). In recent years the price increase has been equally remarkable rising from 28.59 dollars in 2002 to 87.33 dollars in 2008 (an increase of 305.5 percent).

[2] Examples include successive Climate Conference Summits, and the European Union itself, in which transportation and vehicle markets as well as energy providers are regulated. Directives establish maximum contamination levels, including a 20% reduction in greenhouse gas emissions on 1990 levels to be achieved by 2020. These policies all play a role in stimulating and creating conditions for road transport electrification.

[3] Jiménez et al (2012a) summarize the work in this area and analyze the effect of Spain's vehicle replacement plan on prices, sales and the environment.

public authorities to introduce recharging systems that can support the development of electric vehicles; to promote the necessary research and development; and, finally, to include these vehicles in sustainable mobility plans.

The aim of this paper is to review the broad range of measures that the public sector might implement to promote the electric vehicle and to report on the findings of the first pilot programs implemented in various countries. To the best of our knowledge, this is the first time that the public policy measures undertaken to promote the electric vehicle have been presented in a systematic and orderly way. It should be noted that in the discussion that follows we consider measures proposed to promote both electric vehicles and plug-in hybrid electric vehicles.[4]

The rest of the paper is organized as follows. Following on from this introduction, section 2 presents the strengths and weaknesses of electric vehicles in comparison with those of the internal combustion engine. Section 3 reports the main actions taken to date in deploying charging networks, while section 4 discusses measures taken in relation to promote the demand for electric vehicles. Measures to enhance the electric vehicle industry, primarily as part of research and development (R&D) programs, are presented in section 5, while section 6 examines those directed at incorporating electric vehicles in sustainable mobility plans. Section 7 reviews less frequently adopted initiatives, and finally the main conclusions are presented in the last section.

2. Drivers of electric vehicles

Electric vehicles have a number of advantages over ICE vehicles, yet present a number of drawbacks. One of the main reasons for promoting electric vehicles is that they exploit more energy efficient technology than that use by ICE vehicles. As the WWF (2008) and the International Energy Agency (2008) report, electric vehicles are four times more energy efficient than ICE vehicles. In fact, Ahman (2001) shows how vehicles powered by alternative energy (basically, electric vehicles, plug-in hybrid electric vehicles and fuel-cell electric vehicles) are twice as energy efficient as current ICE vehicles.

[4] Srivastava et al (2010) report that the plug-in hybrid vehicle is the next candidate for replacing existing ICE vehicles. The plug-in hybrid vehicle can serve as the bridge between ICE vehicles and full electric vehicles.

This increased energy efficiency can also result in a reduction in greenhouse gas emissions, although the magnitude of these reductions depends critically on the technology used to produce the electricity. If most of the electricity can be produced using sources of renewable energy (solar, wind, etc.), reductions in greenhouse gases will be high, but if the dominant technologies are coal and oil, the reduction will be minimal (Transport and Environment, 2010).[5] As Hadley and Tsvetkova (2009) point out, the impact of the introduction of hybrid or electric vehicles will depend on the technological mix used for electricity generation, as well as the time of day (demand peaks or valleys) when recharging takes place, among others.

A further advantage of the electric vehicle is that it should lead to an improvement in city air quality (as electricity generating plants are typically located some distance away) and noise levels. As Greenpeace et al (2010) report, if the increase in electricity demand coincides with a valley in consumption, this could improve the efficiency of electricity generating plants.[6]

Despite the potential benefits of electric cars, it should be borne in mind that they do not represent an unequivocal panacea. As the Transport & Environment report (2009b) stresses, it is likely that technological advances in electric vehicle development will not be fast enough to ensure compliance with the greenhouse gas limits fixed for the coming decades. Kageson (2005) expresses his doubts about the possibilities of hybrid vehicles being introduced quickly enough, since in 2004 only 8,500 new hybrid vehicles were registered, representing just 0.06 percent of new vehicles in EU-15.

One explanation for the slow introduction of electric vehicles is the obstacles this technology faces when compared to internal combustion. According to the Citi report (2009), the main obstacles are:

[5] Bradley and Quinn (2010) also point to the need to change utility factors if we consider that hybrid vehicles will introduce different characteristics, different driving behaviors, in addition to other factors that can have a significant influence on the utility factor. For the Spanish case, see the analysis provided by Romero (2012).

[6] As Ryan et al (2009) show, it is not only the introduction of electric vehicles that can improve the level of emissions but also an increase in taxes on gasoline, as the latter would help reduce the level of pollutant emissions from the fleet of vehicles. For a comprehensive review of tax effects on levels of contamination see Sterner (2007).

1. Costs. - Although the long-term costs of electric vehicles are not as great as those of ICE vehicles (based on lower maintenance and fuel costs), the cost of acquisition remains higher because of the price of the cell battery pack. Ensuring a competitive purchase price will, therefore, largely depend on the evolution of battery costs (the main cost involved in these vehicles). Predictions of battery costs vary from company to company, but seem to provide for a significant reduction, which should facilitate their competitiveness.

   However, for the time being, and for some time to come, the cost of the battery will remain one of the main obstacles to the adoption of the electric vehicle, so much so that some companies are beginning to spread the cost of the battery, which is being granted under lease. The cost of acquisition seems to be a barrier to the spread of electric vehicles, and has led to public sector intervention through subsidies for the purchase of such vehicles, and to R&D support to reduce battery costs.

2. Infrastructure for recharging. - Although in some cities, such as London, Rome and Berlin, small networks exist for recharging vehicles, the spread of such networks is slow. Charging points installed in homes are slow but relatively inexpensive (around $250), while more rapid charging requires an investment of several thousand euros. The failure to develop recharging networks can induce "range anxiety" in vehicle owners, that is, the fear of not reaching a charging point before the battery dies. This fear can be a significant barrier to the introduction of the electric vehicle, and here the public sector can play an active role in disseminating information about the location of these charging points to help reduce this "anxiety".

   A further point to note regarding recharging points is their compatibility. The homogeneity of systems between countries, in order to avoid any incompatibility, is essential for the diffusion of electric vehicles. Here, there is an obvious role for public regulation.

3. Consumer acceptance. - Various reports conclude that consumers would be willing to make the switch if the electric vehicle reduced energy costs. Pike Research (2009) reports that two-thirds of consumers would even be willing to pay a higher price for the vehicle, under this condition. Thus, a regulatory framework and a set of clear, stable electricity rates are important in ensuring consumers are fully informed of the savings in their energy costs. Measures to facilitate public information

concerning energy supply to the potential consumers of electric vehicles would therefore help in the introduction of electric vehicles.

4. The evolution of other technologies. - The existence of vehicles using other technologies (fuel cell, biofuels, ethanol, hydrogen, etc.) and the conversion of ICE vehicles in more environmentally friendly cars (with higher levels of fuel efficiency) represent obvious competitors for electric vehicles.[7] Identifying the best technology for the future and focusing public efforts in developing this technology will not be a straightforward matter.

In attempts to overcome these barriers, various factors will come into play. These can be classified as being either endogenous (government support, industry initiatives) or exogenous (increases in fuel prices, economic crisis, reduction of fossil fuel reserves) in nature. In this study, we focus above all on the former, but we must not forget the existence of the latter, which may have a significant influence on the adoption or otherwise of electric vehicles. In the case of the endogenous factors, it is not only public authorities that can promote the introduction of electric vehicles but industry too has a role to play in overcoming the barriers that hinder development (especially of batteries and charging networks).

The role of the Public Administration is clearly critical as far as environmental regulations that indirectly promote the use of electric vehicles are concerned. In the case of Europe these include: 1) Directive 2009/28/EC which states that 10% of the energy used in transport must be provided by renewable sources by 2020. 2) The EC regulation 443/2009 which imposes reductions in average emission levels for vehicle manufacturers, setting objectives of 130 gCO2/km for 2015 and 95 gCO2/km for 2020. 3) The European strategy to promote the use of environmentally friendly vehicles (COM, 2010; 186 final) which establishes as priorities the development of electric vehicles that are at least as safe as conventional ones, a European standard for charging points, a public charging network, a smart grid and research programs for the safe recycling of batteries.

If we examine a number of pilot projects implemented in various cities around the world, we can see how the nature and extent of public intervention have changed considerably. Wiederer and Philip (2010) present case studies in four cities that have

[7] For a review of energy efficiency in the car industry see Jiménez et al (2012b).

run pilot schemes for the introduction of electric vehicles and which provide examples of the roles that the public sector might adopt.

- Singapore, in June 2010, initiated a project to invest 20 million dollars in setting up a comprehensive network of recharging points, and to provide subsidies for the purchase of electric vehicles. The primary goal of local government is to attract the electric car industry to Singapore.

- The Indian city of Bangalore has no specific plan to promote electric vehicles, yet there are over a thousand electric vehicles of the REVA brand (a domestic producer) on the streets. This seems to indicate that, at least in this particular case, there is no need for active intervention on the part of the public authorities to promote demand for electric vehicles.

- In the City of London, the scheme has entailed a 17-million pound investment, including the installation of a network of charging stations, the electrification of its public transport fleet and incentives for purchasing and marketing electric vehicles. To develop this ambitious project (submitted in May 2009), the city council's transit agency "Transport for London" is working with a consortium of electric vehicle manufacturers, major utilities in London and car rental companies.

- The City of Berlin has initiated two simultaneous electric vehicle programs, both powered and funded by private industry. The city is administratively limited to helping companies and ensuring the compatibility of the two offers as far as the charging network is concerned.

It is interesting to note how the pilot projects run in these cities have given different emphases to the deployment of electric vehicles: industrialization, in the case of Singapore; full network development, in the case of London; and the recharging network, in the case of Berlin. Likewise, the degree of public sector involvement varies significantly from one project to another: from simple guidelines for private companies (the case of Bangalore and Berlin) to an active role in the market though heavy investment (the case of Singapore and London).

The sections that follow break down the measures applied by the public authorities as they seek to address the main barriers and to promote the development of electric vehicles.

3. Recharge system

Before examining in greater depth the possible barriers that the recharge system might represent to the introduction of electric vehicles, and the main measures adopted by the public sector in relation to them, we outline the various types of recharge and their main characteristics.

As Wiederer and Philip (2010) report there are three types of system: first, slow recharging points or Level 1 points, located primarily in homes, apartment buildings or in public spaces close to residences. It is thought that car owners will use these stations essentially to recharge their vehicles over night, that is, when electricity consumption is in the valley period. However, workplace parking lots or shopping centres are also potential sites for these points and consumers are, therefore, more likely to recharge their vehicles during the day, that is, during peak periods of electricity demand. This may necessitate an increase in the capacity of electricity generation.
Second, there are the rapid charging or Level 2 points, located primarily in shopping centres, supermarket car parks or gyms, and which will also be used during the day. And third, the super-fast or Level 3 charging points, which will be located in line with existing service stations along the highways. The following table summarises the different types of charging points and their main features.

Table 1: Type of recharge systems

Charging level	Specification	Typical use	Time to charge battery
Level 1 (slow)	120V / 13 A	Charging at home / office	7- 8 hours
Level 2 (Fast)	240V / 32 A	Charging at supermarket , gym	3 – 4 hours
Level 3 (Rapid)	Up to 500V / 200 A	Like a normal gas station	30 minutes

Source: Wiederer and Philip (2010)

As indicated in the International Energy Agency report (2008) slow recharge systems are currently almost non-existent, with the exception of a few pilot programs and schemes. In the case of rapid charge systems, the report identifies the need for the deployment of such points in conjunction with the development of battery “swapping” systems. Level 2 points should, it recommends, be located primarily in locations of high-density traffic, stores or public car parks.

High battery costs would make the “swapping” system a viable alternative. However, it would require compatibility between models of electric vehicles and their battery systems. But Wiederer and Philip (2010) believe it unlikely that such standardization can be achieved, so that a “swapping” system would not be able to replace Level 2 points. Yet, such systems might be an alternative in very specific cases such as for a fleet of city taxis where a uniformity of vehicle type (and, hence, of battery type) could make “swapping” a competitive possibility.

Having defined the different types of recharge on the market, we now examine the features and elements that need to be taken into account when developing an efficient charging network.

The first point to bear in mind is the diffusion of information to drivers regarding the location of these charging points (International Energy Agency, 2008). GPS technology can be useful for informing consumers about the nearest available points and about free parking places where vehicles can be recharged. Such information would reduce driver uncertainty and stress, enhancing the utility of electric vehicles and reducing the number of optimal charging points.

A second issue raised by the aforementioned report is the need for standardised charging systems, at least on the same continent. The main features that would need to be standardized are: 1) Plug-in types; 2) Recharging protocols; 3) Communication protocols between cars and recharging systems; 4) Regulations for public recharging that ensure safety with minimal administrative barriers; 5) Battery recycling standards and regulations; and 6) Utility regulations conducted by state/provincial authorities to ensure orderly participation in this market.

A third element to consider is the cost of these charging points, and the tariff system for recovering that investment. The International Energy Agency report (2008) estimates the cost of such infrastructure at between 1,000 and 2,000 dollars per vehicle.

Wiederer and Philip (2010) provide more detailed information by estimating the costs of recharge points by type. For Level 2 points designed for private use (located in private homes or garages), the cost ranges between 500 and 2,500 dollars. If the point of recharge (Level 2) is publicly accessible (located in public garages or on the street), the cost rises to between 2,000 and 8,000 dollars. Finally, for Level 3 points (located along highways and requiring a maximum of 30 minutes to recharge a vehicle) the cost ranges from 40,000 to 75,000 dollars.

Based on these estimated costs, the study analyzes the price (under different levels of use) that would make investment in a charging network viable. According to the authors, the price of electricity supplied to the public charging points (especially at Level 3) would have to be raised considerably - more than 70% on current levels rising to as much as 238%. Such tariff rises would make public charging points quite unattractive to potential consumers of electric vehicles, who logically would opt to recharge their cars at home at greatly reduced rates. Thus, the deployment of a network of public recharging points financed by private companies might be rendered impractical, especially in the case of Level 3 points.

To date, governments and industry have yet to reach an agreement on who should cover these investment costs and how they might be recovered through the charging of fees. It is clear that a major investment in charging infrastructure is required and that national, regional and local authorities will have a significant role to play. The International Energy Agency report (2008) itemises a set of measures that might facilitate the optimal development of charging networks:

- Analyze each region to estimate the relation between demand from electric vehicles and electricity supplies, especially after the initial phase when the demand for electric vehicles is predicted to grow.

- Establish appropriate codes and standards for recharging power supplies and for smart metering.

- Analyse development strategies at the national level to identify infrastructure and priority areas, schedules and funding.

- Define the roles and responsibilities of various stakeholders (governments, regulators, utilities, vehicle manufacturers and consumers) to establish a clear strategy of collaboration and cooperation between different levels of government, as well as with companies and electric vehicle manufacturers.

- Prioritize domestic recharge without neglecting the implementation of a development plan for commercial charging stations, especially as the number of electric vehicles increases.

- Explore the feasibility of various approaches to fast charging methods, such as the “swapping” system.

A fourth point to consider is the role to be played by the smart grid, including the need for next-generation infrastructures and future technological developments. Analyses should also be undertaken of consumer availability for electricity sales and the circumstances under which this might occur.

These four points need to be given careful consideration in the development of an efficient charging network and in ensuring that the charging network does not become a barrier to the growth of the electric vehicle market (Kley et al, 2011). However, these authors point out that with a charging network in private homes, the public charging network may be minimal. Furthermore, they evaluate the problem of financing public charging points, given the low percentage use that they might attract.

Kley at al (2011) likewise identify a set of barriers that might limit or prevent the development of charging networks. They identify three types of barrier: 1) regulatory barriers, particularly the need to fix standards regarding recharging and conditions affecting the sale of electricity (to allow power companies to design their own investment plans) and permits for the installation of charging points; 2) economic barriers, including the uncertainty regarding user demand for recharge, as well as the type of fees to be paid by users at charging points; 3) technological barriers, principally the uncertainty of recharge technology and future applications of smart grids.

The International Energy Agency report and RETD (2010), among others, have outlined joint plans for the introduction of electric vehicles and charging networks in different countries. These are summarized in the following table.

Table 2: Planned vehicle deployment in demonstration projects

Country/Location	OEM	Deployment plan	Timeline
France: Strasbourg	Toyota/EDF	100 vehicles (Prius PHEV)	2009-2013
France: Paris	Toyota/EDF	4,000 vehicles (autolib) 1,400 charging stations	2011
Germany: Berlin	Daimler/RWE	100 vehicles (Smart EV) 3,600 charging stations	2009
Japan: Tokyo	Mitsubishi, Subaru/Tepco	200 charging stations	2009
Spain: Sevilla, Barcelona, Madrid	Various	2,000 vehicles 550 charging stations	2009-2011
Denmark	Better Place Gov.	500,000 charging stations 50 EV´s charging stations in 2009 150 EV/ charging stations in 2012	2011
Ireland		10% of fleet electric (250,000 veh) in 2020 1 M€ R&D and demo plan	2020
Israel	Better Place	100,000 charging stations	2010
Italy: Rome, Pisa	Daimler/Enel	100 vehicles (Smart EV) 400 charging stations	2009-2013
Netherlands: Amsterdam		10,000 vehicles to 40,000 vehicles	2015-2020
Canada: Vancouver	Mitsubishi	Unknown (i-MiEV)	2009
USA: Arizona, California, Oregon, Tennessee, Washington	Nissan	Up to 1,000 vehicles (Nissan Leaf) 12,750 charging stations	2010

Source: IEA-RETD (2010)

Below we describe in greater detail some of these initiatives by broad geographical region. First we examine the development of the charging network in North America (United States and Canada), then in Europe, and conclude by analysing initiatives in the rest of the world.

North America

The Boston Consulting Group (2009) estimates the amount of investment needed to develop the public charging network in the United States at 21 billion dollars. The participation of energy companies, particularly utilities, in the development of this public network will, it concludes, be far from straightforward. As discussed above, a public charging network would generate only limited revenue growth, while the need for investment is high and the risks substantial. The increase in demand for electricity that would be created by the mass introduction of electric vehicles would not have a significant impact on the earnings of these companies; however, they would have to invest heavily in a public charging network near residential areas that might not be attractive to consumers. Note that the electricity prices charged as a result of these investments would be more than twice those charged to home residents, which could well mean that the majority of consumers would not contemplate using these public recharging points. Thus, the participation of power companies in the development of public recharging systems seems unlikely without strong public incentives.

KPMG (2010) reports that two separate bills were presented before the Senate and the House in May 2010 to increase funding for electric vehicle infrastructure: the Senate bill earmarks up to 250 million dollars for 15 municipalities and cities to improve their infrastructure. The House bill offers up to 800 million dollars to five municipalities and 2,000 dollars to electric vehicle owners to install charging equipment.

To fund the charging system and to ensure their economic viability, both Kley et al (2011) and Wiederer and Philip (2010) suggest that annual fees may be a more efficient manner of generating the necessary resources than user payments. Wiederer and Philip (2010) estimate this annual payment at between 100 and 200 dollars, depending on the number of charging and recharging points. Whatever type of business plan is eventually chosen to fund the charging system it should serve eventually to reduce owner “anxiety”, but doubts remain regarding their economic viability.

Europe

Within the European market we report here on three initiatives: one local and two regional.

At the local level, the City of London plans to establish a network of recharging stations throughout the metropolitan area. The goal is to set up 25,000 recharging points by 2015, including a fast-charging network, to be distributed as follows: 500 in the street, 2,000 in car parks and 22,500 in collaboration with the business community and to be located in work places and points of entertainment (Mayor of London, 2009).

In Spain, the Generalitat de Catalunya has devised an ambitious project to deploy 91,200 charging points by 2015. The plan includes the creation of both private and public charging points. The following table shows the specific objectives over the forthcoming years.

Table 3: Objectives of charging stations in Catalonia

Type of charge	**Number of charging stations**					
	2010	2011	2012	2013	2014	2015
Private	600	4100	13000	26000	44800	76000
Private of reinforcement	60	410	1300	2600	4480	7600
Public (park station)	90	230	1040	2080	3584	6080
Public (street)	40	70	130	520	896	1520
Total	790	4810	15470	31200	53760	91200

Source: Generalitat de Catalunya (2010)

As can be seen from the above table, the Generalitat de Catalunya seeks to establish private recharging points for each electric vehicle, while creating a network of public charging points to increase the project's credibility in the eyes of vehicle owners and to reduce their "range anxiety".

To achieve these objectives, the Catalan Government has proposed a set of public support programs and incentives. In the case of private charging points, public support is focused on two features: 1) providing a line of credit to owners of electric vehicles for the installation of private charging points (provided recharge is conducted in valley hours) involving minimum technical requirements as regards legalization; and 2) promoting the installation of charging points in new buildings, especially in public housing developments. In the case of the public charging network, the government is offering subsidies of up to 30% of the investment (up to 600,000 euros) if a private company undertakes to provide the service and grants of up to 40% of the investment for projects aimed at supra-municipal electric mobility (up to a maximum of 200,000 euros). Similarly, the Generalitat de Catalunya aims to reach agreements with the operators of parking lots and municipal entities to ensure that 1.5% of all such lots have a charging point by 2015.

Finally, Meier-Eisenmann et al (2001) report the behavioural patterns displayed by electric vehicles and their owners, by employing a range of methodologies (monitoring charging systems, surveys conducted directly with owners, etc), in their analysis of a pilot scheme conducted in the Swiss canton of Ticino. They report that 56% of owners of electric vehicles use the parking areas reserved specifically for them, rising to 82 percent in the case of four-wheeled vehicles (two-wheeled vehicle owners use these spaces much less frequently - 29%).

Most electric vehicle owners, therefore, take advantage of the reserved parking spaces for recharging their batteries. Specifically, 68 percent claimed to “always” or “almost always” park their vehicles in these reserved spaces. Thus, public charging points located in parking spaces reserved specifically for electric vehicles are popular with owners, above all those of four-wheeled vehicles.

Rest of the world

Outside North America and Europe mention should be made of the Electric Recharge Grid Operator model, and various initiatives taken in Japan, a pioneer in this sector.
Andersen et al (2009) report that Israel was the first country to adopt the Electric Recharge Grid Operator[8], introducing the first prototype electric vehicle in Tel Aviv in May 2008. Plans to develop the network have been underway since 2009. Denmark was the second country to adopt the model in a joint project between the government and country’s main electric utility company, DONG Energy. Later adopters include Australia (in a joint project involving the State of Victoria, the AGL electricity company and the financier, Macquarie Bank) and various municipalities in the Bay Area of California and Hawaii.

Japan boasts over two decades of experience in this sector (see Ahman, 2006, for a summary of all public policies for the development of electric vehicles in this country).[9]
In 1993 Japan initiated a project (ECO-Station Project) aimed at introducing 2,000 recharging stations for clean energy vehicles by 2000. Of that number, around half were for electric vehicles (Hayashi et al, 1994). The KPMG report (2010) notes that in March 2010 Toyota, Nissan, Mitsubishi, Fuji Heavy Industries and Tokyo Electric

[8] The Electric Recharge Grid Operator business model creates a market for the coordinated production and consumption of renewable energy (see Andersen et al, 2009).
[9] Limited not solely to electric vehicles, but extended to other projects aimed at reducing pollution, such as hydrogen vehicles. The WE-NET program of NEDO considers this and the necessary infrastructure.

Power Company established the association CHAdeMo (Charge Move), in order to install standardized, rapid charging points and equipment worldwide.

4. Stimulating demand for electric vehicles

Electric vehicles and plug-in hybrid vehicles can generate a set of significant environmental and cost advantages over their entire useful life cycle, greater than those afforded by traditional ICE vehicles. However, as the Boston Consulting Group report (2009) points out, consumers are most heavily swayed by purchasing price when making consumer decisions, and electric vehicles continue to be more expensive in this regard. Kageson (2005) reports that hybrid vehicles are between 20 and 30 percent more expensive than ICE vehicles.

According to this same report, electric vehicles will remain unattractive unless the acquisition cost is subsidized.[10] The high price of these vehicles, it is claimed, is primarily attributable to the cost of the battery, estimated at $700 per kWh. And only if this cost can be reduced to $500 per kWh, with oil prices remaining at levels between $100 and 120, can electric cars begin to compete with ICE vehicles. The report concludes that public subsidies are essential, therefore, to stimulate demand in the sector. Examples of such subsidies include the 7,000-euro grant offered by the French government for the purchase of electric vehicles, and similar measures adopted in Denmark and Israel.

In addition to such subsidies, or any other type of intervention aimed at reducing the purchasing price, a further measure identified for promoting electric vehicles is the raising of pollution standards for ICE vehicles. As reported in the Transport & Environment document (2009a), fixing contamination levels for ICE vehicles at 80 g CO2/km by 2020 and at 60 g CO2/km by 2025, accompanied by increases in gasoline taxes, would result in a competitive upgrading for electric vehicles, thus increasing market penetration.

Transport & Environment (2009c) reports, however, the potential dangers of considering electric vehicles as zero emission generators. This would be to ignore, first

[10] Various countries have subsidized the price of electric vehicles to ensure a minimum demand, especially in the initial stages of their introduction. The International Energy Agency report (2008) sets out the objectives Governments seek to achieve in this regard.

and foremost, the emissions created in the generating of the electricity consumed by the vehicles. Moreover, as the deployment of electric vehicles would statistically reduce average vehicle emissions, manufacturers would be able to justify selling more ICE vehicles while continuing to comply with current legislation on average emission levels.

Taxes represent a further instrument that could be used to promote demand for electric vehicles. Raising the taxes on gasoline consumption or reducing those on electricity (produced primarily from renewable sources) would modify the relative prices of energy products, favouring the introduction of electric vehicles (see Andersen et al, 2009).

A final option for stimulating demand is to promote the use of public vehicle fleets, courier companies and the like. Kley et al (2011) report that various delivery companies have introduced electric vehicles into their fleets. UPS has started to use electric vehicles for postal services in the Washington area. Similar programs are also being introduced in Europe, where companies such as DHL or TNT are using electric vehicles in cities such as Hannover, Barcelona and Lyon.

Below we outline the main measures being taken to foster electric vehicle demand around the world.

North America

The US Department of Energy (2011) aims to put 1 million electric vehicles on the country's roads by 2015. To achieve this goal, the US has implemented a series of measures to promote the demand for such vehicles. Gallagher and Muehlegger (2011) report that these actions are being performed locally, as well as at state and federal levels. The following table summarises the various initiatives being undertaken by a number of States and cities in the US.

Table 4: State subsidy for hybrid vehicles in United States

Single – occupancy HOV lane access	Income tax credit	Sales tax exemption	Vehicle emissions test exemption	State gov. Purchasing requirement	Registration or excise tax exemption	Parking fee reduction or exemption (cities)
AZ (pilot)	CO	CT+	CO+	MN	DC	Alburquerque,NM
CA+	MD*	DC	MD	NM	IL+	Austin,TX
CO (on hold)	NY+*	ME*	WA	NY	NM	Baltimore,MD
FL	OR	NM+		WI	PA	Ferndale,MI
GA (on hold)	PA					Huntington,NY
NJ	SC					Los Angeles,CA
NY (pilot)	UT*					New Haven,CT
UT	WV*					Salt Lake City,UT
VA						San Antonio,TX
						San Jose,CA
						Santa Monica,CA
						Vail,CO
						Westchester,NY

Note: + denotes incentive targeted at high fuel-economy hybrid vehicles, and * denotes expired program.
AZ (Arizona); CA (California); CO (Colorado); CT (Connecticut); DC (Federal District of Washington DC); FL (Florida); GA(Georgia); IL (Illinois); MD (Maryland); ME (Maine); MI (Michigan); MN (Minnesota); NJ (New Jersey); NM (New Mexico); NY (New York); OR (Oregon); PA (Pennsylvania); SC (South Carolina); TX (Texas); UT (Utah); VA (Virginia); WA (Washington); WI (Wisconsin); WV (West Virgina).
Source: Gallagher and Muehlegger (2011).

Loans and tax exemptions are the most popular measures introduced to date to promote hybrid vehicles (along with such initiatives as access to HOV lanes, and reductions in the price of public car parks, which we discuss below). Gallagher and Muehlegger (2011) provide a detailed summary of these support programs in the US. At the federal level support for the purchase of hybrid vehicles took the shape of a tax break of $2,000 between 2000 and 2005. From January 2006 onward, this became a vehicle loan, the amount of which is linked to the model. In general, these credits are greater than the earlier tax deductions and range from $3,150 for a Toyota Prius to $650 for a Honda Accord Hybrid and the Saturn VUE Green Line. These credits are limited to the first 60,000 units sold by each manufacturer. Toyota and Honda actually exceeded this limit in May 2006 and August 2007, respectively.

State wide, there is considerable variety in the amount of aid provided for the purchase of hybrid vehicles. The following table reports the amounts provided by individual States.[11]

[11] Busse et al (2006) show how the characteristics of car price promotions can affect consumers. For conventional vehicles, sales from producers direct to consumers can result in a 70 to 90 percent discount in the final price, while sales from car dealers reduced final prices for consumers by around 40 percent.

Table 5: State tax incentives in United States

State / **Income tax credits**	**Duration**	**Models covered**	**Generosity range**
Colorado	2001 – present	All, but VUE, GS450h, and Camry*	$2265-$6542
Maryland	2001 – 2004	Civic, Prius, Insight	$1000
New York	2000 – 2006	All	$2000
Oregon	2003 – present	All	$750-$1500
Pennsylvania	2006 – present	Civic, Prius, Insight, Escape	$500
South Carolina	2006 - present	All	$130-$630
Utah	2001 – 2005	Civic	$1537-$1720
West Virginia	2003 - 2006	All	$2411-$3750
Sales tax Waivers			
Connecticut	2004 – present	Civic, Prius, Insight	$1217-$1409
District of Columbia	2005 – present	All	$1226-$3294
Maine	2000 – 2005	Civic, Prius, Insight	$300-$500
New Mexico	2004 - present	Civic, Prius, Insight	$608-$704

*Colorado income tax credits for the VUE, GS450h and Camry begin post-2006. Generosity for Sales Tax Waivers in CT, DC and NM are estimated based on vehicles MSRP.

Source: Gallagher and Muehlegger (2011)

Beresteanu and Li (2011) analyze the effectiveness of such public support plans for increasing the demand for hybrid electric vehicles. They show how these programs have increased sales of hybrid vehicles by 20 percent. The report also discusses the effect on sales of reducing the cost of a barrel of oil to 75 dollars and cutting CO2 emission costs to $177 per ton. The study conducts a simulation to show that the sales of hybrid vehicles would have been between 21 and 38 percent lower if gas prices had not risen between 2001 and 2006. Thus, it appears that the evolution of gasoline prices has a greater impact on the demand for hybrid vehicles than does public support.[12]

[12] Alberini et al (1995) show, using a theoretical model and applying it to the Delaware State program, that the percentage of consumers who changed their vehicle thanks to the aid program was around 5%. Huang (2010) analyses the “cash for clunkers” program in the US. He concludes that an average grant of $4,200 is able to convince between 25 and 30 percent of consumers to change their vehicle for a more energy efficient one. Sivak and Schoettle (2009) note that the energy efficiency of vehicles purchased improved between 0.6 and 0.7 miles per gallon between July and August 2009 thanks to this same program. For a detailed description of the “cash for clunkers” program and other programs for the replacement of older vehicles with more energy efficient ones see Yacobucci and Canis (2010) or Cooper et al (2010).

Diamond (2009) similarly analyses the effectiveness of public aid plans to promote hybrid vehicles. The author concludes that federal aid is of limited effectiveness, resulting in an increase in demand for hybrid vehicles of 18 percent.

It seems such aid programs could have a major impact on reducing emissions, if support was not geographically uniform. Skerlos and Winebrake (2010) claim that if the aid targeted consumers in densely populated metropolitan areas (where contamination is greatest), those in areas with a cleaner power technology mix and those with lower income levels, the adoption of electric vehicles would be higher and it would have a greater impact on pollution levels.

Tax relief programs to increase demand for hybrid vehicles have also been launched in Canada. Chandra et al (2010) report that 26% of hybrid vehicles sold in that country can be attributed to public grants. This increase in hybrid vehicle sales represents a reduction in the sales of mid-range cars, SUVs and some high-performance compact vehicles. The substitution is explained by the similarity in price and characteristics presented by the hybrid vehicles sold in Canada (mainly the Toyota Prius and Toyota Camry).

The authors note that purchases of these hybrid vehicles mean that the average cost of reducing one tonne of CO2 now stands at $195. The aid program was implemented in 2000 when the province of British Columbia introduced a tax exemption for the purchase of hybrid vehicles. In 2006, a further five provinces implemented similar policies. In 2007, the Federal Government started a two-year program to promote the sale of energy-efficient vehicles or vehicles that use alternative fuels through cash rebates.

In 2010 the Government of Ontario offered grants of between $4,895 and 8,321 for the first 10,000 customers who purchased a new electric or hybrid vehicle. The following table (Table 6) shows the main initiatives taken and their characteristics.

Table 6: Measures to promote demand in Canada

Province	**Vehicle eligibility**	**Rebates and timing**
British Columbia Policy announced: August 2000 PST rate: 7% with graduated increases for vehicles over $55K	All hybrid vehicles with regenerative braking (cars and SUV's eligible)	30% of tax paid up to maximum of $500 for vehicles bought before July 31st 2001 30% of Provincial Sales Tax (PST) paid up to maximum of $1000 after July 31st 2001 A point of sale reduction of all PST to a maximum of $2000 after February 16th 2005 Additional rebates in PST (reductions in the graduated increase of PST over 7%) for hybrid vehicles over 55K (see note 1)
Prince Edward Island Policy announced: March 2004 PST rate: 10%	All hybrid vehicles are eligible	All the PST paid up to $3000, for vehicles bought after March 30th 2004
Ontario Policy announced: May 2001 PST rate: 8%	All hybrid passenger cars (with regenerative braking) eligible 2001, SUV's eligible 2002	PST rebate up to a maximum of $1000 for cars bought after May 10th 2001 Hybrid SUVs and trucks included June 18th, 2002 A point of sale reduction of all PST to a maximum of $2000 after March 23rd 2006
Quebec Policy announced: March 2000 PST: 7.875%	See notes (2) below	All PST paid to a maximum of $1000 for vehicles bought after March 23rd 2006 and before February 21st 2007 All PST paid to a maximum of $2000 for vehicles bought after February 22nd 2007 and before January 1st 2009
Manitoba Policy announced: November 15th 2006 PST rate: 7%	See notes (3) below	Flat $2000 rebate for all vehicles bought after November 15th 2006

Source: Chandra et al (2010)

Notes: People buying light vehicles that are priced >$55,000 have to pay a higher PST rate. This rate increases by 1% for the first $1000 over $55,000 and continues to increase by 1% for every additional $1000 to a maximum of 10% (for vehicles costing more than $57,000). For hybrid vehicles the graduated increases come with an additional exemption of $7,000 on the threshold. This means that the PST does not increase for hybrid vehicle until their price reaches $62,000.

Cars eligible for a rebate in Quebec are: 2005 and 2006 Honda Insight; 2005–2007 Toyota Prius; 2007 Toyota Camry Hybrid; 2008 Ford Escape Hybrid (two-wheel drive); 2005–2007 Honda Civic Hybrid; 2005 Honda Accord Hybrid; 2007 Nissan Altima Hybrid.

Cars eligible for a rebate in Manitoba are: Honda Insight; Lexus GS 450H; Lexus RX 400H; Toyota Camry Hybrid; Toyota Highlander Hybrid; Toyota Prius; Chevrolet–Silverado 1500 LS Hybrid; Ford Escape Hybrid; GMC Sierra 1500 SLE Hybrid; Honda Accord Hybrid; Honda Civic Hybrid; Saturn VUE Green Line.

Gallagher and Muehlegger (2011) note that it is not only the Public Administration that offers grants, but that private corporations have begun to provide incentives to employees to purchase hybrid vehicles. In 2004, Timberland returned $3,000 to employees who bought a hybrid vehicle. Google offered $5,000 from March 2005, while the Bank of America returned $3,000 to its employees from June 2006.

Europe

As discussed in section 2, the European Union has introduced regulations to promote the introduction of electric vehicles in its general stock of cars. Denmark has also implemented measures at the national level to promote demand for electric vehicles. It has used the tax system to grant full exemption from taxes on electric vehicles until 2012, making a budget provision for 2008-2011 of more than 35 million DKK.

At the regional level, the Spanish Autonomous Community of Catalonia (Generalitat de Catalunya, 2010) has introduced various measures to promote demand for electric vehicles, aiming for a target of 76,000 vehicles by 2015. One of the key measures here is the introduction of electric vehicles in the Government's own fleet of vehicles. The document seeks to ensure that 15% of public service vehicles are electric by that year.
The second of the measures implemented in Catalonia is a system of grants for such vehicles. During 2011 the Generalitat de Catalunya provided the following grants depending on the type of vehicle: 1) for passenger cars, a contribution up to € 7,000 to a maximum of 15% of the cost of the vehicle; 2) for electric motorcycles (power 4kWh), € 750 euros to a maximum of 15% of the cost of the vehicle; 3) for commercial vehicles, up to € 50,000 to a maximum of 15% of the cost of the vehicle. This amounted to an expenditure budget of 1.5 billion euros in 2009.

The report to promote electric vehicles in Catalonia stresses the need to provide more and better information to users, so as to overcome the barriers discussed above in Section 2, namely the obstacles to innovative change. The report concludes that the Public Administration need to play a proactive role in providing information in all areas related to electric vehicles: purchase decisions, maintenance, life cycles, associated technologies, etc.

Finally, mention should be made of two local initiatives taken in London and Amsterdam. In the case of London, the Mayor offers discounts on the city's congestion charges (worth up to 1,700 pounds a year), and encourages the uptake of electric vehicles via car clubs (Mayor of London, 2009). The British government also offers buyers of electric vehicles a 5,000 pound subsidy (KPMG, 2010). In the case of Amsterdam, the City Council Electric Transport subsidy program has a fund of EUR 3 million and covers up to 50 per cent of the additional costs incurred in buying an electric vehicle (KMPG, 2010).

Rest of the world

In the rest of the world, the first initiative to highlight is that taken in Israel. Here, the government amended its tax system in January 2008, halving the taxes paid on electric vehicles compared to rates for ICE vehicles. Israel classifies its vehicles into 15 categories based on a “green index” (on a scale from 0 to 100 “green points”), where the greener the car, the lower is the tax rate to be paid.

China has also taken measures to increase demand for electric vehicles. Weinert et al (2008) report that the Chinese government has promoted demand for electric motorcycles (E2Ws) by introducing changes in the local regulations of various municipalities (beginning in just 30 cities in 1998 this has now expanded to 148 cities in 2006) so as to reduce ICE motorcycles.

The International Energy Agency (2008) reports that China has also established programs to promote the electrification of vehicles nationwide. From 2008, the Ministry of Science and Technology initiated a series of projects to introduce vehicles using alternative energy in 10 cities. The aim was to reach a total of 500 electric vehicles by 2009 and around 10,000 units by the end of 2010. To this end, subsidies for the purchase of electric vehicles of 50,000 RMB (about $7,300) were introduced, although only the F3DM model benefits from this grant.

Since 1978 Japan has promoted several leasing programs and other incentives to encourage the purchase of cleaner electric vehicles (Iguchi, 1992). Ahman (2006) describes how, under the Environment Conservation Programme in 1995, the Japanese government announced the replacement of 10% of its public vehicles by 2000 with vehicles producing lower emissions. In 2001, the government also established a goal to replace all used vehicles with cleaner alternatives, of which 60% were expected to be hydrogen-electric mix (EVAAP, 2002). In addition, in the 90s various policy measures were adopted aimed at increasing demand for cleaner vehicles (methanol-fuelled vehicles and CNG vehicles).

The city of Delhi (India) has also implemented an aid program (15% discount) for the purchase of electric vehicles. In states such as Madhya Pradesh, Kerala, Gujarat and West Bengal, the excise tax on the purchase of electric vehicles has been reduced by up to 4%, while other cities and states in India have implemented reductions in road tax or vehicle registration taxes.

5. Industrialization and R&D policies

As mentioned throughout the paper, battery costs are the key factor that will determine whether electric vehicles can ultimately be competitive and win market share at the expense of conventional ICE vehicles (Offer et al, 2010). Little wonder, therefore, that most R&D programs target technological improvements to vehicle batteries. The cost of electric vehicle batteries is dictated primarily by their size, weight and energy density, and any progress in these areas would result in substantial improvements to the competitiveness of these vehicles.

The International Energy Agency report (2008) estimates that between 2012 and 2015 lithium batteries will cost between 300 and 600 dollars per kWh. This means that for a battery with a capacity of 20 kWh (the minimum for an electric vehicle), the cost would rise to between $6,000 and $12,000. Clearly, the nearer this price can be kept to the lower band range the better for the viability and competitiveness of electric vehicles. Economies of scale and a decrease in the learning curve should help achieve these cost reductions, but they cannot be guaranteed.

Given the importance of the battery in the total cost of electric vehicles it is not surprising that producers of these vehicles have initiated R&D projects in conjunction with battery producers aimed at improving production of this key element. The following table summarizes some of the projects initiated by vehicle and battery manufacturers.

Table 7: Joint R&D programs initiated by car and battery manufactures

Car manufacturer	Battery manufacturer
BYD Auto	BYD Group
Fiat-Chrysler	A123 Systems, Altairnano
Ford	Johnson Controls-Saft
GEM	Sanyo / Panasonic
GM	LG Chem
Hyundai	LG Chem, SK Energy and SB LiMotive
Magna Group	Magna Steyr
Mercedes-Benz	Continental, Johnson Controls-Saft
Mitsubishi	GS Yuasa Corporation
Nissan	AESC
REVA	Indocel Technologies
Renault	AESC
Subaru	AESC
Tata	Electrovaya
Think	A123 System, Enerdel / Ener1
Toyota	Panasonic, EV Energy
Volkswagen	Volkswagen and Toshiba Corporation

Source: International Energy Agency (2008)

The International Energy Agency report (2008) recommends that governments provide backing for battery producers, especially the most innovative in the sector. Such support should enable the construction and expansion of battery production plants ensuring that investment requirements are not an obstacle to progress. Access to materials such as lithium in the medium and long term makes it increasingly necessary to develop R&D programs that promote the use of materials and innovative designs that can reduce the production costs of electric vehicles. Production costs can be further reduced if battery producers and electric vehicle manufacturers can operate together.

The International Energy Agency report (2008) also stresses the need for technology development programs for the recycling of the batteries from electric vehicles once their life-cycle has ended.

Below, we describe the main initiatives taken by Governments around the world.

North America

The US authorities have been granting support to the electric vehicle industry for many years. As indicated by the Transport and Environment report (2009a), as early as 1973 the US Congress passed the “Electric and Hybrid Vehicle Research, Development, and Demonstration Act” designed to promote new technologies related to electric vehicle batteries and the engines of such vehicles. Despite its ambitious nature, the plan failed to achieve its objectives and was shelved by the Reagan administration.

As part of the more recent US strategic plan (US Department of Energy, 2011), the “American Recovery and Reinvestment Act” (ARRA) greatly expands the resources available for industrial investment, a significant portion of which are assigned to the energy industry. These resources include “tax credits” to build vehicles powered by batteries. Indeed, the US has set itself the goal of being able to produce 500,000 hybrid electric vehicles in 2015.

The US Department of Energy (2011) has encouraged investments through its Office of Science in basic research, channelled through the Massachusetts Institute of Technology (MIT). This has resulted in the development of a new material known as “new nanostructured cathode” which can be applied to battery technology. A company, A123 Systems (Watertown), has been set up to commercialize this new technology and it has been the recipient of aid from the “Small Business Innovation Research Department” since 2002 and the “Office of Energy Efficiency and Renewable Energy” since 2006.

Other lines of support for the development of R&D include the “Partnership for a New Generation of Vehicles (PNGV)” and its successor the “FreedomCAR”, as well as specific programs for electric vehicles. According to Gallagher and Muehlegger (2011), these programs account for a total expenditure of $80 million from the US budget.

Europe

The European Commission has also funded R&D projects via their programs JOULE I and II (Transport & Environment, 2009a). Among the entities receiving financial support are “European Electric Road Vehicle Association” (AVERE) and the “Association of Cities Interested in the Use of Electric Vehicles” (CITELEC).

A number of countries have also undertaken their own programs of technological development, working from different perspectives. Thus in France, Italy and Sweden several companies are jointly conducting R&D programs in the development of electric vehicles, albeit under the auspices of different governments. In Germany, however, it is the private sector that is making these investments, while the Government has taken a much more laissez faire approach.

In the case of Spain, the Catalan administration has not neglected R&D policies in its overall strategy for the introduction of electric vehicles. It two main policy proposals to promote industrialization and R&D in the sector include 1) an attempt to establish a battery-pack manufacturer in Catalonia; and 2) communication projects between the grid and electric vehicles budgeted to the tune of 35 million euros for the years 2011 and 2012. Other initiatives have also been taken (with a budget of 173 million euros) to promote research projects related to the development of electric vehicles.

Rest of the world

Japan's industrial policy in relation to the development of electric vehicles (including vehicles powered by clean energy) has been highly active, as evidenced by Ahman (2006). The MITI has promoted electric vehicles (BPEVs) since 1971, launching a five-year government-industry R&D programme. The MITI has also funded company R&D programs. Between 1978 and 1996 it lent support to leasing projects (MITI, 1990). The Japanese government, through MITI, has promoted various policies for "Demonstrating the Feasibility of BPEVs" in combination with Intelligent Transportation Systems, research on lithium batteries, and developing high-energy efficient hybrid vehicles (see Ahman, 2006).

Initiatives in China should also be highlighted. As Brown et al. (2010) report, this country has allocated ten million Yuan (1.46 billion dollars) to a program to help the auto industry carry out technological innovation projects.

6. Program development and management of sustainable road mobility

In this section we draw on the proposals contained within the general plan to promote electric vehicles, as drafted by the Generalitat de Catalunya (Catalonia, Spain), in order to explain the measures that can help introduce such vehicles within programs of sustainable mobility. The following specific measures are forwarded:

1) A reduction in the time and financial costs of travel. Permission for electric vehicles to use the High Occupancy Vehicle (HOV) lanes and a differentiation in the tolls charged according to levels of contamination would help achieve these objectives. In 2009, London's mayor proposed reviewing the possibility that electric vehicles might use the HOV lanes, as introduced in the city of Oslo (Norway).

2) Establishment of “Park & Ride” sites at interchanges. Such car parking facilities, sited in city outskirts, would allow owners of electric vehicles to leave their cars charging while they are at work.

3) Agreements with private companies to install charging stations in firms’ car parks. The report even considers the possibility that such charging points would serve as the point of association with private electric vehicles.

4) Financial support from the Institut Català d'Energia for the implementation of pilot programs that improve the energy efficiency of companies’ transport systems. These companies receive up to 60% of the investment, provided they demonstrate an increase in energy efficiency of at least 5% in the displacement of workers from their homes to the workplace. Here, electric vehicles offer a competitive advantage in attaining this saving.

5) An information system designed for electric vehicle owners that allows them to quickly identify the nearest charging points. The introduction of clear, visible and uniform signs to help identify the recharge points is also useful in reducing the “anxiety” of the owners of electric vehicles.

For the US market, Skerlos and Winebrake (2010) also identify the use of HOV lanes as being one of the main measures for promoting sustainable mobility. In fact, as Diamond (2009) reports, implementing this measure increases the demand for hybrid vehicles in the United States. Consequently, it has already been introduced in the following states: Virginia, California, New York, Florida and Utah.

Table 8: Permission for hybrid vehicles to use the HOV lanes in the US

State	Date
California	August 10, 2005
Florida	October 1, 2005
New York	March 1, 2006
Utah	September 1, 2006
Virginia	June 30, 2006

Source: Diamond (2009)

7. Other policies and their implications

In addition to the four main policy areas outlined above, there are other measures and factors that can influence the deployment of electric vehicles. The International Energy Agency (2008) has published a set of cross-section recommendations that should serve to promote the development, penetration and consolidation of electric vehicles. Market security is an essential element for vehicle and battery manufacturers to safeguard the investments required. It seems advisable, therefore, for government authorities to set transparent, medium-term goals and criteria so that private players in the industry can make efficient decisions.

The report also points out the need not to opt, as far as possible, for a given technology, but rather to fix set goals (e.g. a given reduction in CO2 emissions) and that it should be the private actors that determine which technology is the most efficient for achieving these objectives. The Government, together with industry, should even organize educational programs to increase consumer confidence and understanding of electric vehicles. Likewise, disseminating information about the operation of electric vehicles (including battery life, recharge times, location of charging points, type and cost of repairs, etc.) can help increase consumer trust in these vehicles.

A key element to consider in the development and subsequent market penetration of electric vehicles is product standardization. As Brown et al (2010) stress, standardization in the battery recharging infrastructure, electricity distribution and accounting for the environmental characteristics of this energy, and different features of smart grid technologies would help significantly in the introduction of electric vehicles.
Good battery performance is also a key factor affecting the implementation of electric vehicles. In this regard, the U.S. Department of Energy's "FreedomCAR and Vehicle Technologies Program" promoted through the "Advanced Vehicle Testing Activity (AVTA)", tests the reliability and durability of batteries installed in hybrid electric vehicles or plug-in hybrids.

Karner and Francfort (2007) report outcomes from their analyses of the sets of batteries installed in such vehicles today. They show that battery life is significantly reduced in the presence of air conditioning and that some batteries fail before their theoretical life is reached (e.g. the Honda Insight battery begins to fail at 72,000 miles). They conclude that if consumers are to purchase these vehicles then they need to be reassured that the batteries will perform and that ultimately they will be economically profitable.

Besides the benefits of electric vehicles and the economic policy measures that can help promote them, we need to take into account possible drawbacks resulting from their introduction. Indeed, the identification of the problems their deployment might generate should help minimize these and, eventually, ensure their success.
WWF (2008) reports that massive deployment of vehicle batteries will greatly increase the amount of raw materials required for their production. Moreover, the batteries will have to be properly recycled once they reach the end of their useful life cycle if serious environmental problems are to be averted.

A further element to consider is the impact that the introduction of electric vehicles might have on electricity production. As Hadley and Tsvetkova (2009) point out, if the recharging of hybrid vehicles is not undertaken solely during valley periods, then the increase in peak time demands could lead to a price hike. Indeed, any increase required in production capacity would significantly raise the costs of introducing the hybrid vehicle.[13]

This problem has also been noted in a study conducted in Catalonia (Spain) by the Generalitat de Catalunya (2009). The report proposes the creation of a fee “super valley” to serve as an incentive to the owners of electric vehicles so that they recharge their batteries at times of low electricity demand. Increasing consumption would not only require an increase in production capacity, but would necessitate a more efficient use of the currently installed capacity. Differentiating between day- and night-time electricity prices is also recommended by the report of the International Energy Agency (2008) as being essential in controlling the impact that electric vehicles will have on electricity consumption. The Transport & Environment (2009b) report reaches similar conclusions.

A final point to bear in mind is that the greater efficiency provided by electric vehicles should result in the increased share of road transport, which in turn could lead to increased net energy consumption.

[13] See Green II et al (2011) for a detailed analysis of the impact of the introduction of plug-in hybrid vehicles on the electrical distribution network.

8. Concluding remarks

Increasing fuel prices and growing environmental concerns are two key factors enhancing the potential of the electric vehicle as a valid alternative to the internal combustion engine. However, electric vehicles must still overcome a host of barriers (both technical and economic) if they are to compete with traditional vehicles.

The aim of this study has been to describe the main drivers of the development of electric vehicles, as well as the public and private policies that have been adopted, or might be applied, for promoting these vehicles as alternatives to ICE vehicles. In so doing we have analyzed the key points of reference in the field, undertaking a review of policies being implemented around the world.

We conclude that the development of an extensive charging network capable of overcoming the problems of “range anxiety”; the ability to guarantee sufficient demand for electric vehicles so as to maintain such charging networks; and the development of batteries (the principal component of an electric vehicle) that can provide greater autonomy while ensuring lower production and replacement costs are the goals that must be achieved if electric vehicles are to be successfully incorporated in the automobile market.

In overcoming these barriers, the role that the public sector plays will be crucial. Thus, most industrialized countries have implemented, in one form or another, public measures for just this purpose. These measures can be classed into four categories: first, the development of both public and private charging infrastructure or systems; second, traditional subsidies or tax breaks for the purchase of environmentally friendly vehicles (electric, hybrid, etc.); third, industrialization and R&D policies which, among other factors, reduce battery production costs (main expense in constructing these vehicles); and finally, the inclusion of electric vehicles in sustainable mobility programs. These are just some of the measures that public agencies can implement to help overcome the technological and economic barriers that limit the introduction and consolidation of electric vehicles.

The geographical spread of these measures is concentrated principally in the industrialized Northern Hemisphere, where Japan has most experience, not only in terms of the involvement of its public administration in implementing different strategies of public funding, but also as regards its collaboration with the private sector to develop new technology (hybrid) batteries, etc. Elsewhere, the regulations introduced by the European Union and the measures taken by its member states, the United States and Canada represent the chief examples of attempts to develop the electric vehicle.

Today, many countries are implementing these, or similar, measures to facilitate the introduction and consolidation of the electric vehicle so that it might become the mode of transport of the future. However, the barriers remain considerable and greater involvement is required from the public administration to tackle “the chicken or the egg” dilemma faced by the sector and the negative effects that a poor tariff regulation would have on the electricity market.

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