TRIGGERING THE DEVELOPMENT OF ELECTRICAL MOBILITY: A REVIEW OF PUBLIC POLICIES

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ABSTRACT

The fundamental challenge of a massive deployment of electric mobility is the reduction of transportation's impact on climate. Hereby derived challenges specifically concern: (i) the organization of mobility together with the uptake of recharge infrastructure, (ii) the interaction of the electric mobility system with the electricity net, hereby considering the energy storage function of batteries, (iii) the technological progress and the industrial production of vehicles and various components. Overall, these stakes involve the community more than the individual vehicle user.

This paper analyses public policies and projects in favour of electric mobility based on private or shared vehicle usage. An international review of national policies and regional projects is given. The conditions for availability and attractiveness of an electric mobility system to potential users are discussed, notably so with respect to the deployment of the recharging infrastructure and its adequacy to existing land-use patterns.

1 INTRODUCTION

1.1. Background

The rise of the automobile began at the end of the 19th century with electrically powered vehicles, but the internal combustion engine became dominant from 1910 onwards, because of the advantages in size and range offered by liquid fuels. Car travel developed hugely over the 20th century as a result of technical progress and falling costs for infrastructure (routes, roads, equipment), vehicles (performance and reliability, comfort and ergonomics), systems (signage, traffic management) and services (fuelling, maintenance, insurance, rental and taxis). In the developed world, automobile infrastructures became widespread and the private car became the dominant method of individual transportation, enabling people to access a wide variety of activities both local and remote.

However, the car also generates problems: accidents, noise, air pollution and greenhouse gas emissions, consumption of increasingly rare and expensive fossil fuels. The last three forms of impact have become very significant issues of sustainable development: since they are associated with the internal combustion engine, one major way of reducing them is to use electrically powered engines.

Electrical mobility has a low carbon footprint (provided that the electricity is not generated from fossil fuels), and can employ renewable energy. It has less local impact on noise levels and air quality. It entices green driving habits and quieter traffic conditions. However, it requires a battery, which is expensive and has limited range (in terms of journey distance).

1.2. Motivations for Public Action

In short, replacing internal combustion vehicles with electric vehicles is advantageous to the community but more costly for the user. In order to achieve the community benefits, electrical mobility needs to be made attractive to users, not just by developing its availability in terms of vehicles and charging infrastructure, but also by ensuring its long-term affordability over the lifespan of the vehicle, or rather throughout the period of vehicle ownership.

Availability. All the components entailed in a car-based mobility system, as described in paragraph 1.1, are supplied by a number of players involved in a long-term complementary relationship. The shift to electrical mobility primarily concerns the supply of energy and its local distribution to users, with a dense network of charging terminals. The authorities are in a strong position to encourage coordination and cooperation between the different suppliers.

Affordability. To absorb the additional acquisition costs through energy savings, the essential condition is that the vehicle should be used to travel significant distances, typically more than 20,000 km a year, with strict constraints in terms of range. This condition can be met by intensive individual use, or by the vehicle being shared between different users for variable rental durations (from very short to long). An additional solution would be to cut acquisition costs by reducing the cost and improving the performance of batteries.In the long term, therefore, the community can promote the development of electrical mobility by ensuring availability and stimulating technical progress. It can also act in the short term, through various provisions to encourage electric vehicle ownership and use: tax incentives for purchase and ownership, lower prices for usage or parking, advantageous parking provisions, etc. This kind of provision would apply during a transitional phase, until the spread of electric vehicles reached the critical mass required to generate economies of scale in the production of vehicles and components.

Related issues. Finally, the development of electrical mobility is closely tied up with energy generation and industrial production, both of which are strategic issues for the community. The presence of large numbers of electric vehicles on the roads would require significant increases in electricity production, using green sources to ensure a positive impact on the environment. At the same time, the batteries would effectively become small reservoirs that could smooth out electricity production over time, with potential economic gains for the battery holder. As regards the industrial production of electric vehicles, in many industrialised countries the car industry plays a significant role in creating both jobs and value.

1.3. Objective and Scope of the Paper

We have defined the stakes of public policy to promote electric mobility. The main purpose of the article is to identify the targets and instruments of such a policy, through an international review of policy briefs, implementation plans and practical experiences. In looking at public policy, we identified three distinct sectors: Industry, Energy, Mobility and related infrastructure. Each sector is associated with a specific spatial scale, primarily national for industrial and energy policy, primarily regional for mobility and the related infrastructure, but sometimes also for energy. Two types of vehicle are considered: entirely electric or rechargeable hybrid vehicles. Two forms of transportation are concerned: the user-owned private car and the shared car owned by a rental company.

1.4. Structure of the Paper

The rest of the article is structured into four sections. Section 2 provides a typology of political instruments in terms of policy targets. Section 3 looks at the following examples of national policy: China, Denmark, European Union, France, Germany, India, Japan, Spain, United Kingdom, United States. Section 4 examines three regional cases: London, the

Ruhr in Germany and the Vorarlberg region in Austria. Finally, section 5 discusses the policies from a sustainable development perspective.

2. TYPOLOGY OF POLICY INSTRUMENTS

The introduction of a new mobility product, such as the electric vehicle, faces a variety of obstacles. Governments playing a key role for the development of an electro-mobility system can actively influence the whole market on its demand and supply sides. The gist of an International Energy Agency report on deployment strategies for new technology vehicles [1] is, however, that the scope of policy instruments influencing market development should go far beyond the traditional direct State regulations and financial incentives. Priority should be given to network management, where the State acts as facilitator. Platforms that include all actors of the mobility system should be established to develop a joint, economically viable strategy for an EV deployment. Such an approach is likely to be more time consuming but also more successful than massive programs aimed at selected, stand-alone targets. Of course a network management approach requires the setting of legislative regulations. Financial incentives can play an important, but only complementary role. In the following a typology of possible governmental measures supporting the introduction of EVs is given. The categorization is in line with [1] and [2]; it also includes measures found in current policy intervention programs (see [3] and section 3).

Command and control instruments are usually in the hands of public authorities and applied at a country wide level. Traditionally, they represent the core of a government's strategy that is then complemented by other types of instruments. Command and control instruments are neither costly for the public budget nor very time consuming for the government. Their effectiveness stems from their legally binding character that mainly obliges EV-system supplying stakeholders to provide products that conform to quality or safety standards. Also emission regulations or licensing procedures including environmental criteria can force developers and manufacturers to adopt cleaner technologies and create a trend towards EVs. The consumer side can be encouraged by including environmental criteria on issuing contracts for the purchase of public service vehicles; by mandates that enforce the inclusion of EVs into public sector fleets (or enforce vehicle retailers to sell a fixed percentage of EVs per year); by exempting EV users from restrictive regulations (as e.g. parking and driving restrictions). Command and control instruments have to be adapted to market and technological developments throughout time.

Economic instruments are purported to overcome the cost barrier to EV development. These instruments support the development of EV technology or give financial incentives to potential buyers. Instances include direct investments in R&D or infrastructure, preferential pricing policies (e.g. road pricing based on emissions, preferential parking fees), subsidies for EV purchase or EV infrastructure construction and tax incentives for EVs (e.g. concerning fuel taxes, circulation taxes/motor taxes, registration/purchase taxes). Also, special financing schemes that help overcome the barrier of high investment costs can be offered. Economic instruments should not be implemented as stand-alone measures, since the diffusion of an innovative technology requires behavioural changes that involve a set of conditions broader than financial incentives.

Procurement instruments are aimed to push the demand for clean vehicles, hence to increase the number of them and enable for scale economies in their production. A government or a consortium of stakeholders decides to purchase a set of clean vehicles, of which the number enables them to benefit from reduced prices. Also, initiators of an EV program can decide to use EVs and take leadership by example by spreading information about their experiences. 'Green' procurement for public and industrial fleets can be introduced on a voluntary or mandatory basis.

Collaborative instruments pertain to the network management approach by a government, based on the principle that the State should exert a collaborative and managing role in the society and the markets. The government takes a coordinating role between manufacturers, researchers, authorities and customers. Certifications and labels can be introduced for improving transparency and diffusion of information on the market; voluntary agreements between manufacturers and public authorities are decided; public-private partnerships favouring new mobility practices are established.

Communication and diffusion instruments consist in informing and educating the public in order to develop their interest for and acceptance of EVs. Simultaneously, new mobility practices are encouraged among the public. Measures include the setting-up of information and awareness campaigns, marketing activities, the provision of buyer guides and vehicle labelling, education and training activities for vehicle-salespersons, mechanics and conversion-shop-employees. Lobbying activities, realisation of demonstration projects, development of target group specific EV offers and the marketing and demonstration of possibilities for changing mobility behaviour also play an important role.

A further **supplementary instrument** is to develop public transport in synergy with electric mobility by allowing interfaces with car-sharing services and vehicle rentals as well as by installing necessary (recharging) infrastructure and common tariff schemes of PT in combination with individual, electric transport means.

Governments are likely to select a certain package of instruments with respect to the existing framework, the capability and financial capacity of the country. The capability depends on specific country characteristics, including the geographic and economic situation. To be effective, a policy package should combine all kinds of instruments in a comprehensive and balanced way: network management, framework conditions, economic incentives and fleet procurement, communication and diffusion, and multimodal transport policy.

3. REVIEW OF NATIONAL POLICIES

This section explores governmental strategies and initiatives on a national level in order to reveal currently preferred deployed measures. Reasons for and trends of a policy framework for the support of EVs are shown. Mid- and long term objectives of discussed countries are sketched.

3.1. Country cases

3.1.1 The European Union

End of April 2010 the European Commission released the 'European strategy on clean and energy efficient vehicles' [4]. The strategy is purported to encourage the development and uptake of clean and energy efficient vehicles. Europe declares its aim to become market leader and technological champion for clean and energy efficient vehicles, while promoting sustainable growth and reducing the EU's dependency on fossil fuels and its emissions resulting from the transport sector.

The strategy envisages to continue and to revise the current regulatory framework laying down standards and regulations of vehicle emissions, to support R&D in green technologies (to be further defined by 2011), to support consumer information and market uptake by introducing EU-wide electro-mobility projects and to engage in international standardisation activities and dialogues. Concerning EVs specifically, the European Commission wants to make sure to achieve Europe-wide standards for communication and recharging infrastructure. Further, funding for EV infrastructure development on national and regional level shall be made available and ways for stimulating investment in infrastructure and EV services are to be defined. Life cycle analysis of different new vehicle technologies will be carried out in order to evaluate the impact of the increased requirement for low-carbon electricity on the electricity supply system and on the grid. The EU will take initiatives for assuring sustainable secondary use of batteries and EVs' end of life. For this purpose research programs especially on recycling and reusing of batteries are promoted.

The European Roadmap 'Electrification of Road Transport' [5] released in October 2009 gives a consensus of major companies and organisations. In an introduction period till 2012, 200,000 (PH)EVs shall be deployed. Demonstration and field tests shall be carried out; first niche applications shall evolve. In an intermediate phase until 2016, 1 million EVs/PHEVs are to be deployed. Technology advancement and enlarged infrastructure shall allow the dissemination of the vehicles over various cities and regions. From 2018 onwards mass production of the new vehicles is to start, turning (PH)EVs, together with further battery advancements, sellable without any subsidy. 5 million vehicles shall be deployed by 2018.

In November 2008 the European Commission launched the PPP Green Car Initiative [6]. By now EUR 5 billion (EUR 4 billion are provided as loans through the European Investment Bank) have been made available for the support of R&D on technologies and infrastructures that are essential for achieving 'breakthroughs' in the use of renewable and non-polluting energy sources, safety and traffic fluidity. Projects related to fully electric and hybrid electric vehicles have gained of importance throughout the last years. Also the CIVITAS [7] program for cleaner and better transport in cities specifically defines 'clean fuels and vehicles' as one out of eight categories of measures. 25 projects throughout various European cities have been launched in this context.

3.1.2 Germany

In January 2009 the German government approved the 'Economic Stimulus Package II', where one out of 14 resolutions specifically addresses electric mobility. Within this framework EUR 500 million has been made available for investments in R&D in the general benefit of electric mobility for the years 2009-2011. Then in August 2009 a 'National Development Plan for Electric Mobility' (NEPE) [8] was adopted, which lays down the clear goal of deploying 1 million EVs by 2020. By 2030 more than 5 million EVs shall be deployed, by 2050 most urban transport shall do without fossil fuels. Until 2020 the development plan foresees the following three stages:

- A *market preparation phase* until 2011 mainly serves for advancements in research. Points of focus are energy storage systems, vehicle technology and system and grid integration. First recharge stations shall be deployed and several demonstration projects will be launched.
- A succeeding *market escalation phase*, lasting until 2016, then foresees the introduction of EVs into the market and a broader infrastructure installation that covers numerous towns.

– From 2017 onwards a *mass market* of EVs shall be created. Mass production of EVs and (probably) lithium-ion batteries within Germany are envisaged.

The main stated goals of Germany are meeting energy and climate policy targets, developing a lead market for electric mobility, maintaining and expanding the country's competitiveness, and fostering new mobility practices in order to achieve a considerable improvement in the quality of life. Besides a slight reduction in taxation, so far no other measures encouraging EV demand have been stipulated.

3.1.3 United Kingdom

The United Kingdom wants to leave the technological development open to the market. Favouring of specific technologies is avoided. The Office for Low Emission Vehicles (OLEV) released a policy paper on 'Ultra-Low Carbon Vehicles in the UK' [9] in 2009, which, however, mainly refers to (PH)EVs. The policy paper defines the following strategy:

- *Short term* (-2015): Support is given to demonstration projects and to the transformation of urban centers to EV cities. Consumer incentives are implemented to stimulate demand.
- *Medium term* (2015-2020): Continued improvements to the efficiency of new cars are envisaged. Coverage of charging infrastructure is to be increased. (PH)EVs are produced on a large scale.
- *Long term* (2020+): From 2020 onwards, a continued roll-out of charging infrastructure shall take place. This shall allow the development of a mass market of ultra-low carbon vehicles that results in a complete decarbonisation of the road transport by 2050.

The main incentives for the UK for investing into the development of (PH)EVs are of environmental and economic nature. The transportation sector shall be decarbonised, national economic competitiveness and growth shall be supported, and life, health and safety shall be improved.

As of mid-2010 the UK has already committed over £450 million of support to encourage the development and uptake of (PH)EVs. £230 million are reserved for the '*Plug-in car grant*' [10] program, which supports motorists of an ultra-low carbon vehicle with a subsidy of up to £5.000 until 2014. The '*Plugged-in places*' [11] program aims to create a critical mass of infrastructure in 3 to 6 lead cities or regions. £30 million were made available. The '*Infrastructure grant program*' [12] provides grants to encourage organisations to install refuelling or recharging stations for alternative fuels. A '*Low Carbon Vehicle Procurement Program*' [13] is supported by altogether £50 million and aims to use the public sector's purchasing power to accelerate market introduction of lower carbon vehicle technologies. R&D support in the field of (PH)EVs of more than £220 million is provided through the Technology Strategy Board for the '*Integrated Delivery Program*' [14] and the '*Ultra Low carbon Vehicle Demonstrator Competition*' [15]. Further, the UK government announced to increase fuel taxes till 2013. EVs do not pay any fuel duty or vehicle excise tax and are subject to the lowest percentage of the company car tax [16].

3.1.4 Spain

In April 2010 Spain's government announced its expectation of having some 70,000 EVs in circulation by 2012. 250,000 EVs are to be deployed by 2014. Comprising also gasoline-electric (plug-in) hybrid cars, altogether 1 million low-emission cars shall be on Spanish roads by 2014. The main reasons for aiming at these numbers are to reduce carbon emissions and Spain's dependency on energy importations. Further, introducing EVs is seen as an important stimulus in innovation and as a necessary contribution to the sustainability of the transport system. [17]

In September 2009 the Spanish government announced to spend EUR 10 million on kick-starting the use of EVs until 2011 [18]. The hereby financed Movele project [19] aims to introduce 2,000 EVs of various categories across a broad range of companies, institutions and private individuals, for use in urban environments, and to set up 500 recharging points. In February 2009 demonstration projects were announced in the three cities of Seville, Madrid and Barcelona. In April 2010 further EUR 590 million were announced for subsidies and tax breaks concerning the purchase of EVs. The subsidy covers 20 % of the purchase price of an EV (up to a maximum amount of EUR 6.000). [17]

3.1.5 Denmark

The Danish government acknowledges that EVs can significantly contribute to a reduction in the use of fossil fuels. Next to environmental stakes, energy security is the main reason for this government to support the market penetration of EVs. The goal is to replace a quarter of the 2 million cars in circulation with electric cars by 2020 and achieve a penetration rate of 94% on the market of new vehicles at that epoch. [20]

Due to a green tax policy [21] there is an extremely high registration taxation (of up to 180%) on combustion engine cars. EVs are exempted from this taxation at least until 2012.

In February 2008 the Danish government signed an energy agreement, which features a test scheme for EVs [20]. The test scheme's goal is to generate new specific and practical experience with EVs and the required infrastructure. The test scheme shall also help shed light on the opportunities for integrating EVs as a flexible storage facility into the Danish electricity system. DKK 35 million (~EUR 4.5 million) have been set aside for the test scheme in the period 2008-2012. In 2009 Denmark became after Israel the second country that fully cooperates with Better Place [22]. An extensive recharging and battery swap infrastructure is rolled out. 500,000 charging points and 150 battery swap stations are envisaged. Further, also a large scale demonstration project [23] is taking place on the island of Bornholm. Especially the vehicle-to-grid concept is tested.

3.1.6 France

France has ambitious targets concerning EVs. Until 2015 the market share of EVs of newly sold vehicles shall have reached 7% (16% in 2020, 27% in 2025) and 450.000 vehicles shall have been deployed (2 million by 2020, 4.5 million by 2025). [24] In October 2009 a national plan for the development of EVs was released. The document was updated in April 2010 and gives an overview of all (foreseen) initiatives in order to successfully launch a broad-scale introduction of EVs. The development of EVs is seen as a twofold opportunity in order to fight against climate change, while simultaneously restructuring an economic sector/the whole economy. [25]

The 'Automobile Pact' released in February 2009, foresees a EUR 250 million loan for the industrialisation of decarbonised vehicles. The 'Grand Emprunt' (announced in December 2009) foresees EUR 750 million for the development of decarbonised vehicles. This funding will be invested in several research and deployment projects under the patronage of the French Environment and Energy Agency (ADEME). Specific funding has also been made available for the construction and development of a battery production factory with a capacity of up to 350,000 batteries. The eco-conception of batteries and their recycling are research priorities. In order to guarantee EV demand to the biggest French auto manufacturers (Renault and PSA), a purchase group of 20 industry partners was formed that guarantees a demand of 50,000 vehicles within 5 years (starting from 2011). In order to assure the supply of appropriate recharging infrastructure, laws have been released that oblige every new building equipped with parking units to connect these to electricity supply by 2012. Car parks at work places have to be equipped with electricity connections by 2015. Further, EUR 60 million has been made available for the installation of 1,250 public recharging points around 20 agglomerations till 2012. By 2025 a recharging infrastructure of 9.9 million points shall have been established around France (thereof 9 million private points, 750,000 public normal charging and 150,000 public rapid charging points).

EVs profit from the highest bonus of an emission based bonus/malus system, being EUR 5,000 per vehicle. This measure has been guaranteed at least until 2012.

A French-German working group succeeded in developing a joint approach to standardisation, which ensures the interoperability of EVs and charging infrastructures. The outlined recommendations will be put into action within the framework of a Franco-German pilot project in the region between Strasbourg, Karlsruhe, Mannheim and Stuttgart. [26]

3.1.7 USA

The American Recovery and Reinvestment Act of 2009 (ARRA) [27] is the most recent legislative act that specifically supports the development and use of a variety of alternative fuel and advanced vehicle technologies. It shall fund research on and industrialization of alternative vehicles in order to put 1 million environmentally friendly vehicles on US roads by 2015. The main motives for the US government to support the development of alternative fuelled vehicles mainly lie in the energy security of the country. Further, it is stated that the US wants to compete with foreign nations in the race to be world leader on renewable energy, to create jobs and to hereby lay the foundation for lasting prosperity, to advance the economic recovery, and improve the environmental sustainability. [28]

In 2009 President Obama announced that $2.4 billion out of the ARRA budget are specifically dedicated to the acceleration of the manufacturing and deployment of batteries and EVs. [28] [29] 48 new advanced battery and electric drive component manufacturing and electric drive vehicle deployment projects in over 20 states are funded. The ARRA dedicates funds to further programs/incentives that (partly) contribute to the development of EVs. Some important instances concerning EVs are [27]:

- The *Qualified Plug-In Electric Drive Motor Vehicle Tax Credit* that contributes between $2,500 and $7,500 to the purchase of a new qualified (PH)EV, depending on the battery capacity and the gross vehicle weight.
- The *Alternative Fuel Infrastructure Tax Credit* that subsidises the expenditures for installing alternative fuelling equipment. The credit amount goes up to 50% of the equipment costs (not to exceed $50,000). Private consumers receive a tax credit of $2.000.
- The *Manufacturing Recovery Provisions Tax Credit* - a 30% tax credit for investment in advanced energy property manufacturing facilities.
- The *Support for fuel-efficient vehicles in the federal fleet* - a $3 billion fund for the acquisition of more fuel-efficient vehicles for the federal fleet by September 30, 2011.

Most measures concerning alternative vehicles are, however, defined on different (mostly state) authority levels. Statistics show that California is the state that provides the widest set of incentives and implements the most stringent legislation concerning alternative fuels. [30] In the framework of the *Advance Technology Vehicles Manufacturing Loan Program* (ATVLP) [31], $1.6 billion were accorded to Nissan North America to build advanced EVs and to build an advanced battery manufacturing facility. $465 million were accorded to Tesla Motors to manufacture electric drive trains and EVs in California. The US also engages in the *U.S-China Electric Vehicles Initiative* [32] that aims at developing joint standards and demonstration projects, a joint technical roadmap and jointly organised yearly forums to bring key stakeholders together. The *Japan-U.S. Clean Energy Technologies Action Plan* [33] encourages the development of mutually beneficial energy science and technology projects.

3.1.8 Japan

In April 2010 Japan released the 'Next Generation Vehicle Strategy 2010' [34]. New vehicle technologies are to be supported simultaneously until 2030. However, until the year 2050 a full-scale diffusion of (PH)EVs shall have taken place [35]. The cruising distance of EVs shall reach up to 500km and battery costs shall have reduced to 1/40 of the current price. By 2030 the governmental diffusion target is to achieve a next-generation vehicle percentage of 50-70% of newly sold vehicles. It is estimated that up to 30% could be made up by (PH)EVs. The remainder should be covered by hybrid, fuel cell or clean diesel vehicles [34].

The main objectives for creating a next-generation vehicle strategy were to improve fuel efficiency (and hereby to improve energy security), to reduce CO2 emissions, to diversify the energy mix, and to introduce next-generation vehicles to the market on a full-scale basis. The Japanese automobile industry shall hereby maintain its leadership in high-rate technical capacity on the global market by creating new industry sectors and by acquiring new markets. The country's economy and employment shall be driven and also the competitiveness of Japan's automotive industry is to be maintained. [36]

The 'EV & pHV Towns' concept [37] [38] is an implementation framework to demonstrate fully-fledged dissimination of EVs and PHVs. In cooperation with municipalities, automobile manufacturers, power companies and local enterprises, an intensive development of infrastructure for (PH)EVs is pursued in 8 different urban regions. Demand is initiated by the government, the municipalities and corporations; it is then extended to taxis or car-sharing systems; and finally to private users by fiscal incentives in automobile prices.

The Japanese government has introduced temporary tax reductions/exemptions for fuel-efficient vehicles lasting till April 2012. (PH)EVs are completely exempted from taxes [37].

3.1.9 China

In China a national strategy of leapfrogging to EVs emerged around 2008. The objective of having a manufacturing capacity of 500,000 new energy vehicles (pure electric, hybrid and other alternative energy vehicles) by 2011 was defined. The new cars shall represent 5 % of annual new passenger car sales. In case this goal is achieved, China becomes one of the top five countries producing alternative energy vehicles. During the year 2010 several policy publications on clean vehicles are expected. Also a series of standards on EVs and battery systems will be published in 2010. The main drivers for Chinese government to push the development of new energy vehicles are to sustain the growth of the automobile industry, lessen the dependency on imported fossil fuels and to reduce the pollution caused by automobiles.

To stimulate usage of clean vehicles in the public transport sector, the government announced a package of measures in 13 pilot cities that belong to the first batch of '1,000 new energy cars in 10 cities project'. Over a three year period (start in January 2009) 10 pilot cities are selected each year that put 1,000 hybrid or pure EVs on the road. Further, new energy vehicles will be gradually integrated into the national government vehicle purchase system. Measures on stimulation grants to individual consumers are being formulated and expected to be published in 2010. The highest value of grants is expected to be EUR 5,000 for hybrid cars and EUR 6,000 for pure EVs. [39]

3.1.10 India

In December 2006 the Ministry released the '*Automotive Mission Plan 2006-2016*', which lays down the roadmap for future development in the automotive industry [40]. The manufacturing and assembling of fuel efficient and hybrid vehicles appropriate for the Indian market is a recommended measure. Conversion of vehicles to alternative fuels is to be encouraged and innovative R&D projects are to be supported.

India has the ambitious electric car manufacturer REVA Electric Car Company (RECC), which designs, develops, manufactures and sells EVs. Its chairman strongly calls for appropriate government support that could help transform the landscape of urban India by reducing pollution, improving public health, creating employment opportunities and impacting society. According to RECC, EVs have not gained popularity owing to lack of adequate and timely support from central and state governments. However, RECC aims to have 100,000 EVs on the roads by 2020. [41]

According to [42] the government is contemplating to bring a policy to promote EVs in India. An inter-ministerial group is currently conducting a feasibility study. The policy is likely to be finalised this year.

3.2. Synthesis

Each country under review has assigned a set of stakes to the development of EVs, including primarily the reduction of environmental impacts – on climate and local quality of life. This stake is common to all countries. Two other stakes are invoked depending on the country: energy security and industrial policy. Only the stake of industrial policy makes an issue of international competition. The climate stake is global, whereas the production of green energy is mostly a national matter.About the objectives, most governments address simultaneously the development of demand and that of a charging infrastructure, plus R&D objectives if there is a stake of industrial policy. Comprehensive policy packages are devised, which include framework design and equipment standardization, demand stimulation using fiscal incentives, cooperative procurement of large fleets of vehicles, the implementation of charging spots and the deployment of pilot projects in selected areas. The packages are aimed to promote alternative energy vehicles, basically pure electric or plug-in hybrid, sometimes also hydrogen or bio-fuel.

Denmark is an extreme case because of the high tax on the purchase of a new classic vehicle.Most countries consider explicitly a development path made up of three steps: from Initialization by pilot projects and procurement initiatives, to a Long Run step where EVs hold a large share of the car stock, passing by a Medium Run step which involves taxi and shared-car fleets. The development of green energy sources is mentioned in orientation documents but does not seem to be planned jointly with the first stage of the implementation path.

4. REGIONAL CASES

4.1. London

The Mayor of London launched an Electric Vehicle Delivery Plan in May 2009 [43] [44]. It sets out the roadmap to deploy charging infrastructure for privately-owned EVs up to 2015. Altogether 25,000 charging points shall be installed and 100,000 EVs are targeted on London's roads. The main reasons for the city of London to promote EV development are to reduce carbon emissions, to improve air quality and to reduce noise.

Infrastructure: The city of London envisages making three main types of charging points in the public access charging network available. Slow charging points (6-8 hours charging time), fast charging points (30min -3 hours charging time), and rapid charging points (15-20 min charging time, battery swap system) shall be deployed. The development of the private charging network, in residential homes, at workplaces and for new developments will be supported.

Besides residential off-street charging points, installations at private car parks and customer car parks take the biggest share in the network (altogether 22,500 installations). The public charging network is envisaged to comprise 500 on-street charging points and 2.000 installations in publicly accessible car parks. The main goal is to ensure that every Londoner will be no more than one mile from the nearest EV charging point by 2015.

Vehicles: London aims to increase the number of EVs on the capital's streets as soon as possible to 100.000 vehicles (or 5 % of London's fleet). To achieve this target the city will continue with EV trials and to increase the share of EVs in the Greater London Area (GLA) group fleet. It will also encourage the use of EVs amongst its suppliers. EV options for the wider public transport, as e.g. for taxis, private hire vehicles and buses, shall be developed and the private sector shall be encouraged by incentives to acquire EVs and a marketing initiative.

Incentives and Marketing: The city of London supplies the EV users with incentives that complement the national UK ones. A number of boroughs offer subsidised parking for EVs, saving the user up to £6,000 a year. Also, there is a 100 % congestion charging discount for EVs (being worth up to £1,700 per year for regular travellers). For marketing and communication purposes, a strong and easily recognisable brand for EVs in London will be developed. A pan-London interactive web site will be developed that provides exhaustive information on EVs in London and e.g. on the location of vacant charge points. A call centre for help and advice and to report any issues is envisioned. It is foreseen that the EV scheme will initially operate as a flat fee membership scheme, whereby EV owners pay an annual membership fee to access any of the 2,500 publicly accessible charging points. The aspiration is, however, that the scheme moves to a 'pay as you go' model.

4.2. Germany's model regions – North Rheine-Westphalia [45] [46]

Out of Germany's funding of EUR 500 million for the development of EVs, EUR 115 million are allocated to the establishment of 8 electro-mobility model regions. Stakeholders of science, industry and all participating authorities (regions, cities, communities) work closely together to ensure that electric mobility becomes an integral part of the transport system. Model regions refer much to centres of excellence, where EV related research is carried out, where incitation to new research companies in these fields are given, where vehicles and infrastructure are developed and manufactured and where test fleets are employed and evaluated.

4.2.1 North Rheine-Westphalia including model region Rheine-Ruhr

One of the model regions is the Rheine-Ruhr area, located in the region of North Rheine-Westphalia (NRW). NRW set the goal of bringing at least 250.000 electrically powered vehicles to the market. They want to significantly increase the market share of suppliers from NRW in the overall German market for electric mobility and promote the settlement of new automobile manufacturers in order to utilize the market opportunities. EVs shall be developed to market readiness and market launch.

For this purpose NRW wants to attract players in industry and science to settle in their region and therefore promotes EV directed activities by EUR 60 million (additional to the existent federal funding of the German government). NRW attracts with an already experienced ‘auto cluster’. 12 universities offer automotive-related studies and conduct research on behalf of the automotive sector. Electricity supply is covered by three of the five largest German supply companies based in NRW. The establishment of customer-friendly charging stations has begun. There are about 25 institutional facilities and private enterprises that work in the field of battery technology. Around 40 institutes and private enterprises work in the field of automotive engineering for EVs. 30 players are engaged in the field of developing infrastructures and networks. The model region Rheine-Ruhr focuses on the introduction of individual fleets and public fleets (buses, taxis etc.). Also car sharing models and other new mobility concepts shall be developed, tested and supported by sufficiently broad scientific activities. Within the framework of 7 ‘starter’ projects, 220 EVs were deployed until mid 2010. Until mid 2011 the first test phase shall be completed and successive project plans shall be derived and planned.

4.3. VLOTTE Project, Vorarlberg, Austria [47]

VLOTTE is the project title of an EV demonstration and testing program taking place in the Western part of Austria, Vorarlberg, since August 2009. It belongs to the biggest EV model regions in Europe.In 2008 the Austrian Climate and Energy Fund selected Vorarlberg to become a model region of electric mobility and appointed EUR 4.7 million to its development. The “backbone” of the region is the Vorarlberg Rhine Valley. The Rhine Valley is characterized by a relatively low population density and a simultaneous homogeneity of the settlement structure: an urban-sprawled landscape.

In the year 2009 100 EVs were distributed and assigned to interested parties of an exclusive circle: 40 cars were given to companies, 40 to public institutions, non-profit organisations and associations and 20 to private users. The customer is offered a “mobility card” for approximately 500€ a month (depending on the vehicle). The mobility card includes, apart from the leasing of the car, maintenance costs of the electric parts, a railway pass of the Vorarlberg Public Transport System and the free-of-charge refilling at all public energy recharging stations. After four years the car is purchased by the customer for a residual value of 25% of the initial purchase price. In addition, VLOTTE-customers get free membership to the Austrian Automobile Association.

Vehicle and Energy Supply: Different types of vehicles have been supplied to the project participants. Most of them were produced by the Norwegian car producer TH!NK. All of the VLOTTE vehicles use Sodium-nickel batteries.The energy used for vehicle operation is compensated for by regional, renewable energy production - mainly from solar panels specifically installed for the project.

Charging and its infrastructure: The vehicles can be charged using any ordinary electricity plug. The regional electricity supplier offers reduced tariffs at night. Charging takes on average 7-8 hours, which is drastically reduced if 3 phase-current is available. Furthermore every project participant has the possibility to charge his vehicle for free on the public charging infrastructure network in Vorarlberg (which currently comprises 32 charging stations), in Germany, Switzerland and Liechtenstein. Both the cars and the filling stations got equipped with measuring devices in order to analyse the energy demand on a disaggregate basis. The collected data are used to decide upon expanding the charging network.

Within almost a year the VLOTTE vehicles made more than 150.000 km. However, more than 200 interested people had to be short-listed due to insufficient supply of EVs. The success of the project led to a second step, VLOTTE II. Here, the focus will be given to the establishment of so-called 'mobility-hubs' – vehicle sharing points where besides EVs also electric scooters and electric bikes can be hired. The VLOTTE fleet will be expanded to 250 vehicles; the number of charging points shall be augmented.

4.4. Provisional synthesis

Three cases make a limited set of instances. Let us nevertheless identify first the common features then some peculiarities. The common features pertain to (i) the stakes of environment preservation and the improvement of local quality of life; (ii) the objectives to foster electric mobility and to provide a charging infrastructure. Industrial policy including R&D is a distinctive feature of the Rheine-Ruhr region.The Austrian, Vorarlberg case is remarkable in two features: first, the local production of green electricity to supply the power required by the fleet of EVs; second, the cooperative approach that involves a wide range of actors. As of now, the three cases correspond to the implementation of pilot projects with several tens or hundreds of vehicles. They benefit from substantial public funding, so the economic performance of their EVs is not yet demonstrated.

5. A CONCLUDING FORWARD LOOK

5.1. Towards an economics of functionality in the sphere of mobility

The electric vehicle offers potential users an economic advantage if the additional acquisition cost is offset by savings on vehicle use, which requires significant mileage to be covered. This may suit certain categories of private users, or services providing shared vehicles, which fall within the category of an "economics of functionality".

In addition, for equivalent mileage, an electrical engine experiences less wear than an internal combustion engine, so the vehicle's technical lifespan is likely to be longer, resulting in fewer vehicles being produced and also perhaps the development of renewal services for private cars. In addition, recharging systems constitute an additional infrastructure, which would increase the role of infrastructure in automobile transportation and spread its use more widely across users. Finally, the size of the vehicle stock and charging infrastructure will need to be matched to the area, based on its mobility needs and its financial and renewable energy resources. The transition to electric vehicles could offer an opportunity to design an automobile system of appropriate dimensions.

5.2. Technological and industrial factors

The technological factors relate partly to the vehicle and its components, in particular the production of cheaper and more efficient batteries, and partly to the vehicle's external components, in the charging infrastructures (fast charging or battery swap systems) and the interface between user and system. This interface would need to cover several aspects:

- The interface for drivers, who plan their journeys and have to manage range constraints by scheduling charging stops that may influence their routes and even their destinations.
- The interface for the user of a shared vehicle service, such as remote vehicle or parking reservation systems and tariff management systems.
- The interface for battery holders, to offer economical charging and possibly optimise the cost of global domestic electricity consumption.
- The interface for managers of electric vehicle fleets, to ensure that an adequate number of sufficiently charged vehicles are available at all times and at the right place.
- The interface for operators of shared vehicle services, to optimise vehicle distribution and encourage users to contribute to vehicle repositioning in the depots, and also perhaps to manage real-time vehicle sharing for high-demand routes.

These interfaces have a dual software and hardware form, with on-board and/or centralised control units. The ergonomics of all the different user interfaces need to be as simple as possible, in order to avoid increasing the pressure on range and reservation constraints.
For the future of the transportation network, two types of interface seem crucial: the shared vehicle interface, which is critical for the co-evolution of operations and customers with their patterns of usage; and the interfaces with users to facilitate connections with other transportation modes (in particular parking and mass transit systems). Here, we are back with the question of how mobility is organised: there is likely to be a shift towards more considered and more rational use of the different modes of transportation.

We referred above to the industrial issues in terms of vehicle production and renewal. Other industrial factors include interface production and management and above all the running of vehicle recharge or rental services.

5.3. Towards closer integration between transportation and energy supply

Ultimately, electrical mobility is motivated by climate and energy concerns. At the global level, significant expansion would require corresponding expansion in the production of low carbon electricity, generating a domino effect for other electricity requirements. A large stock of batteries will form a distributed, but globally huge, energy storage resource: they offer potentially significant synergies with energy production from green but inconsistent sources such as solar and wind power.

At the disaggregate level, fast vehicle charging will place large numbers of intense, localised demands on the national power grid. The power grid will need to evolve accordingly, and potentially even more to allow energy to be uploaded from the batteries, if they become media for distributed electricity storage. This development seems consistent with the integration of local green electricity production, and with "domestic" electricity management systems, under which individual households will control their own electricity production, storage and consumption.

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