EVS26
Los Angeles, California, May 6-9, 2012

Electric Vehicle Cities of the Future: A Policy Framework for Electric Vehicle Ecosystems

David A. Beeton
Director, Urban Foresight Limited, 8 The Crescent, Newcastle upon Tyne NE7 7ST, United Kingdom,
david.beeton@urbanforesight.org

Abstract

Electric vehicles (EVs) can make cities smarter. Preparing for mass adoption of EVs requires the creation of complex ecosystems of technologies, policies, markets and commercial structures. Significant investments are being made around the world to develop these ecosystems, which is creating new opportunities to advance a range of smart city concepts.

Drawing on the findings of a global task force commissioned by the International Energy Agency Hybrid & Electric Vehicle Implementing Agreement, this paper outlines a framework that structures a holistic vision of EV ecosystems. This quantifies the domains with which EVs interface in cities and a range of policy considerations related to mobility, smart grids, buildings, services, communities and economies.

The importance of developing this future-oriented outlook lies in the recognition that growth in markets for EVs is by no means certain. Many present day pilots are primarily concerned with establishing the necessary conditions to introduce EVs to cities. However, it is also necessary to develop strategies that nurture markets to future stages of maturity. Accordingly, developing a holistic outlook will help create long-term policy frameworks that maximise the effectiveness of interventions, incentivise private sector investments and enable anticipation of potential barriers to mass adoption of EVs.

Keywords: EV, policy, infrastructure, market

1 Introduction

In a rapidly urbanising world with an increasing strain on global resources and local infrastructure, cities need to be smarter. The size and nature of the challenges faced demand a fundamental reinvention of urban systems. This requires integrated approaches that combine solutions to different smart city priorities, such as mobility, energy, lifestyles and urban design. Yet all too often activities tend to exist in silos, with little consideration of their potential impact or benefit elsewhere.

An electric vehicle (EV) is an example of a cross-cutting technology that has potential to advance opportunities beyond its essential purpose of mobility. Governments, cities and regions around the world are making multi-billion dollar investments to support the introduction and operation of EVs. This is creating new opportunities to advance strategies and solutions for smart cities.

The reality, however, is that many of the pilots and initiatives underway today are almost exclusively focused on creating the necessary conditions to support market introduction of EVs. This reflects the fact that simply establishing EV readiness is itself a significant undertaking, requiring a large amount of coordinated effort amongst a diverse array of stakeholders.

Recognising the importance of future outlook in maximising the effectiveness and longevity of the investments being made today, this paper outlines a framework to advance a holistic and integrated vision for smart EV cities of the future. This draws on the emerging findings of the EV Ecosystems task force which has been commissioned by the International Energy Agency Hybrid & Electric Vehicle Implementing Agreement (IA-HEV).

2 Electric Vehicle Ecosystems

An EV ecosystem defines the total system of infrastructure required to support the operation of EVs. This includes interfaces with hard infrastructure such as recharging technologies, energy grids, buildings and transport systems. It also requires the provision of soft infrastructure such as regulation, information and communications technologies (ICT), commercial services, skills and community engagement.

The concept of an ecosystem recognises the interdependencies between many of these factors. It also provides a metaphor for understanding the complex network of business relationships within and across industries [1]. This can be related to the body of literature on systems of innovation which define the various landscapes of institutions, corporate actors and processes that contribute to industrial and societal innovation [2].

Applying the ecosystem concept to the case of EVs begins to quantify the need to align the provision of essential technologies and supporting policy measures between a variety of public and private stakeholders. This includes government, municipal authorities, automotive manufacturers, energy companies, transport operators and ICT suppliers.

3 The Role of Cities and Regions

Cities and greater-city regions have emerged as the logical geography for many of the pilots to inform the development and design of EV ecosystems. This can be attributed to a number of factors, such as the driveable range of EVs and the importance of local knowledge in identifying suitable locations for recharging infrastructure.

As a result, cities and regions have become the main facilitators and integrators of these new technologies and supporting systems.

To advance the necessary technologies and supporting systems for EVs, recent years have seen an increasing number of pilots across the world. These pilots have largely followed a model of "*typical technology diffusion initiatives*" which invariably involve the dissemination of technical information and know-how and the subsequent adoption of new technologies and techniques by users [3]. In addition to informing the design of supportive infrastructure systems, the pilots have also informed the development of specific policy measures to accelerate the diffusion of EV technologies and tighten links between technology developers and users.

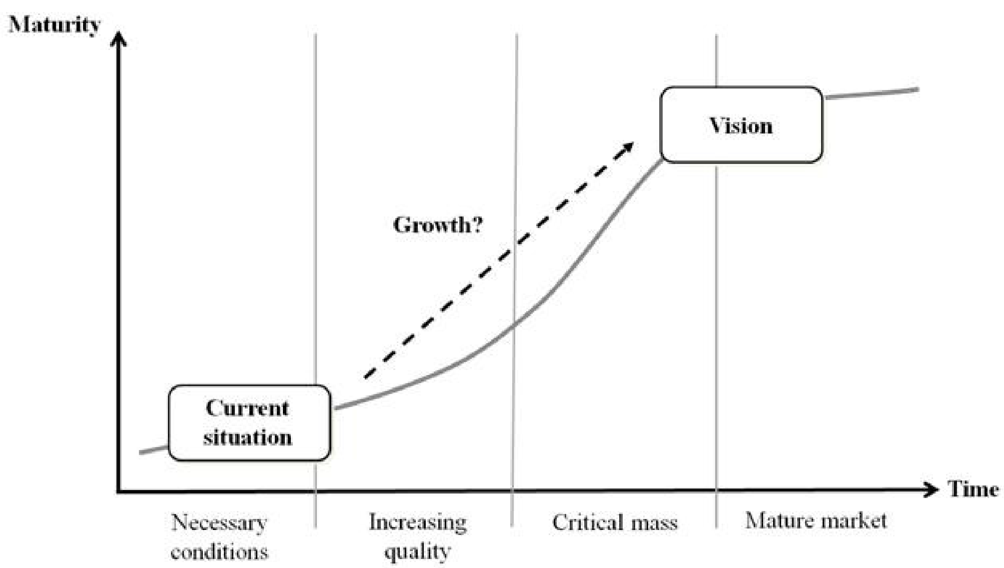

Figure 1: Planning for different stages of growth in markets for electric vehicles

4 What Comes after the Pilots?

Many important lessons and challenges can be identified from the experiences of pioneering cities and model regions. However, it is important to recognise that much of this work is focused on creating the necessary conditions for the introduction of EVs. While this is extremely important, strategies to nurture markets and technologies must also evolve over time to anticipate and satisfy future requirements in ecosystems for mass adoption of EVs.

The importance of developing this future outlook is shown in Fig.1, from which two major imperatives can be drawn. The first is the need to shape a vision on the future commercial and technological considerations that will underpin mature markets for EVs. The second is to acknowledge that achieving growth in markets for EVs is not certain and will require strategies and interventions at different stages of maturity. Developing this future outlook will help to ensure that investments made today are futureproofed and that measures are taken to remove potential barriers to mass adoption of EVs.

In developing strategies for different stages of market growth, Rogers [4] offers a widely cited technology diffusion model to describe the adoption or acceptance of a new product or innovation, according to the characteristics of defined user groups. This model was adapted by Moore [5] to suggest that for discontinuous or disruptive innovations, there is a gap or chasm between the first two adopter groups (innovators/early adopters), and the early majority (see Fig.2). This argues that visionaries and pragmatists have very different expectations and illustrates that growth in markets for EVs is by no means a foregone conclusion.

5 EV Ecosystems Project

The EV Ecosystems project was launched by IA-HEV in November 2010. IA-HEV is an international membership group collaborating under the International Energy Agency (IEA) Technology Co-operation Programme.

Formally known as IA-HEV Task 18, the overarching aim of the EV Ecosystems project is to advance international policy and the design of EV ecosystems for smart cities. The project is capturing examples of best practice and bringing together international experts in workshops to shape a global vision on the technologies, policies, markets and commercial structures that will underpin future developments in EV ecosystems.

To date the project has engaged an international community of experts from industry, governments and research from 17 different countries to contribute to the following process:

- ***Foresight workshops*** are assembling experts from municipalities, regional authorities, governments and industry to establish future priorities for EV programmes and explore specific areas of opportunity including business models, social change and smart grids.
- ***An International Roadmap*** will identify international best practice, showcase pioneering projects and establish an expert view of the emerging challenges and opportunities in EV markets, technologies and

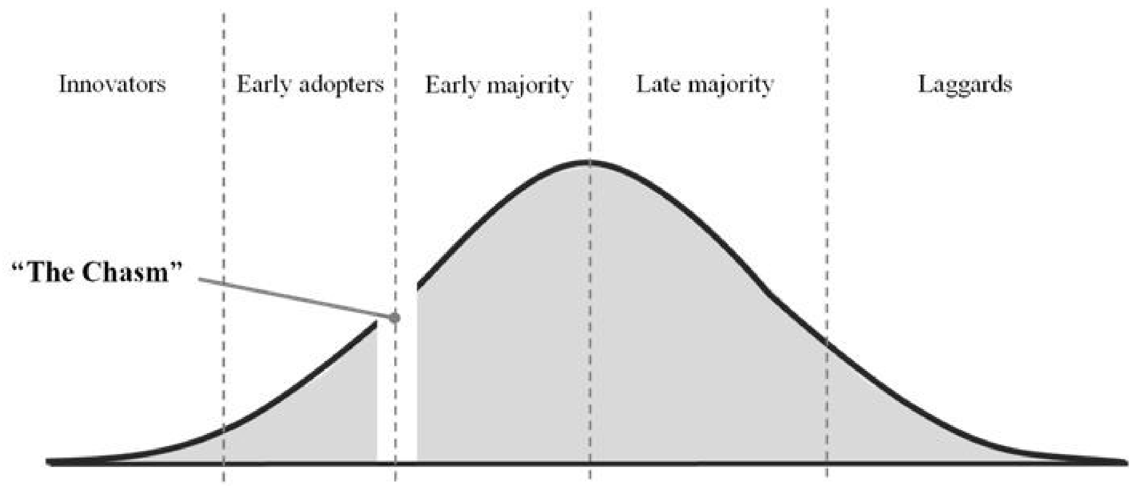

Figure 2: Technology adoption lifecycle [4 and 5]

services.

- ***A web portal*** developed at University of California will provide a database of pioneering EV programmes and connect international experts to facilitate policy exchange and problem solving.
- ***Conferences of Pioneering EV Cities and Regions*** are convening the individuals that are shaping the future development and design of EV ecosystems.

A key output of the project to date has been the development of a framework to structure research and data collection activities in the project. This provides an integrated and holistic overview of the potential for EVs to advance a variety of related smart city concepts.

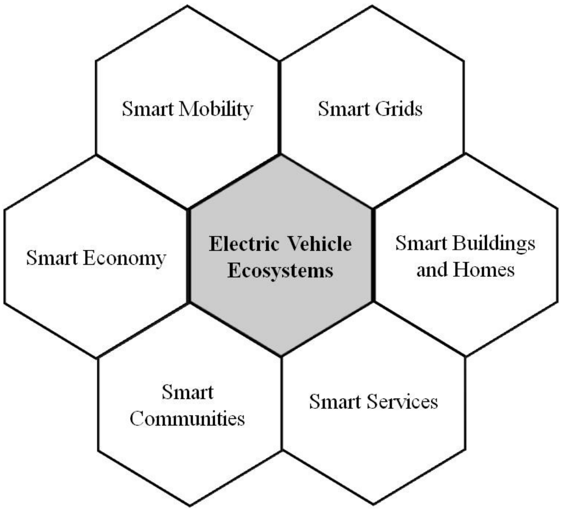

Figure 3: A policy framework for EV Ecosystems

6 A Policy Framework for Electric Vehicle Ecosystems

There are two perspectives that have had the greatest influence to date on international EV pilots and policy. The first is a vehicle-centric perspective which categorises EVs as preferable alternatives to internal combustion engine vehicles. This invariably sees policy and investment decisions balanced against the prospects for alternative transport fuels such as hydrogen and biofuels. Such programmes are variously motivated by reducing emissions from road transport, energy security through decreased dependence on fossil fuels and economic support for the automotive industry.

The second perspective is a grid-centric view which is focused on the impact of EVs on electricity networks. This characterises an EV as an electrical appliance and is motivated by anticipating the long-term impact on electricity networks and the associated needs for grid augmentation and management of recharging behaviours.

The reality is that both of these perspectives are important to cities and demand appropriate strategies and policy frameworks. However, there are also additional domains with which EVs interface that require consideration by policymakers and city managers.

To structure the data collection activity in the EV Ecosystems project, a framework has been developed to quantify the breadth of influence of EVs in an urban environment. This establishes linkages to the six areas shown in Fig.3, which are outlined in the following sections.

6.1 Smart Mobility

The need for a broader mobility paradigm than offered by the vehicle-centric perspective is demonstrated by considering some of the instruments to promote the adoption of EVs. Policy interventions such as purchase incentives, free parking and exemptions from congestion charging are all important in growing markets for EVs. However, they could also be seen to be encouraging more people to drive more often which contradicts many of the underlying motivations for these policies. A broader framework is therefore necessary which also promotes measures to reduce kilometres driven and considers factors such as congestion, safety, accessibility and social wellbeing.

Smart mobility more generally considers the movement of people and goods around cities. This requires consideration of a city’s entire transportation system and how mobility can be made more effective by ICT.

On a simple level, consideration of different transport systems operating in cities encourages EV applications other than cars. Electric bikes, motorcycles, buses, taxis and delivery vehicles are all being piloted in different cities around the world and offer potential to make important contributions to urban transport systems. A key consideration in supporting these alternative mobility platforms is that they may ultimately require different commercial and operating models. For example, the standard electrical connectors for recharging electric two-wheelers are different to those being deployed for cars.

Beyond siloed applications of EVs in different modes of transport, the broader concept of mobility aims to enable travellers to plan and execute journeys across the whole spectrum of available transport options whilst enabling more vehicles to flow more freely through existing infrastructure. This requires that connections are made between a range of different stakeholders and technologies. For example, extension of integrated and smart ticketing initiatives to include EV recharging infrastructure will enable EVs to be better integrated with public transport systems. This also reduces the need to create expensive new back office systems to manage networks of recharging infrastructure.

The technological enablers of connected and smart mobility networks generically fall into the domain of intelligent transport systems (ITS). These technologies are already having a significant impact on the operation of EVs. For example, satellite navigation and route planning technologies are important in estimating the driveable range of an EV and for locating the nearest available charging point. Similarly, the arrays of sensors carried by modern vehicles are providing automotive manufacturers, leasing companies and insurers with streams of data on environmental conditions, the performance of the vehicle and the driver.

The concept of a connected vehicle also offers opportunities to improve entertainment, productivity and scope for new business models in areas such as dynamic insurance, road pricing, car pooling and location-based advertising. While much of these systems are not specific to EVs, advanced technologies for real-time monitoring of battery state of charge and the physical act of plugging-in vehicles could create opportunities for data transfer and a range of innovative commercial offerings.

6.2 Smart Grids

The basic concern for utilities is to safely supply energy to EVs and to reliably absorb any increase in load on the grid. Hence, pilots have largely focused on the provision of infrastructure in different locations (e.g. public, residential, workplace) and the trailing of charging technologies (e.g. standard, AC/DC rapid, inductive). However, as with ITS, developments in ICT are also set to transform energy networks and the way in which consumers interact with these services. The objective of these smart grids is to achieve greater control over generation and demand for electricity.

Conceptual definitions of smart grids invariably identify EVs as an important component. Smart and controlled charging of a large number EVs in cities is seen as a way to change the supply-demand paradigm whereby instead of generating to meet demand, consumption is managed to meet the available generation capacity. In general terms, this requires that EV drivers are encouraged to recharge their vehicles at times of surplus generation capacity and discouraged from charging at times of peak demand. This is particularly important in supporting the large-scale integration of renewable energy generation and managing the associated intermittent supply.

The ability to remotely control EV charging also offers a way to manage demand. The concept of interrupting charging events to reduce the load on the network is a way of creating a proxy to a spinning reserve, which is where operators extend the network capacity by increasing generation output. The main advantage of minimising the demand for this peak supply is that reserve generation capacity is invariably from capital and carbon intensive sources such as gas.

While shifting demand is attractive, a real advantage of EVs is that they also offer opportunities for mobile energy supply. This could see EVs exporting energy back to the grid (vehicle-to-grid) or managing some section of demand within the home (vehicle-to-home). This could be extremely important in managing the growing number of decentralised renewable energy sources in homes and workplaces.

Harnessing the potential of EVs to balance energy demand and supply requires developments in a range of supporting systems. This includes communicating pricing signals to consumers, demand forecasting, remote control and monitoring of energy use. There will also be operational measures such as business models, pricing structures, technical standards, safety regulations and financing models that will be required in deploying the necessary smart infrastructure.

Nevertheless, the potential benefits are significant. In particular, the contribution of EVs to more effective management of network utilisation has the potential to increase reliability, support the decarbonisation of energy generation and reduce the need for costly network expansion and augmentation.

6.3 Smart Buildings and Homes

EVs have the potential to catalyse a range of technologies and policies that encourage the development of smart homes and buildings. For example, EVs will change the financial as well as environmental attractiveness of on-site renewable energy generation. This will see high-cost and carbon intensive transport fuels displaced by energy from local renewables which notionally have zero cost and zero emissions.

The concepts of the connected car and an EV as an intelligent appliance will also see integration with developments in home area networks (HAN). These networks will connect devices and appliances in the home to offer new functionality and control as well as providing a smart metering system to better manage energy demand.

These developments are strongly aligned with vehicle-to-grid and vehicle-to-home technologies. However, the practical application of these systems will require new standards and certification. This will necessitate modifications to building codes and electrical regulations and require inspectors that are trained in understanding the interconnected roles that the individual devices play [6].

Beyond energy use, policy and regulatory frameworks for new housing and commercial buildings also need to be aligned to support growth in markets for EVs. This could include incentivising allowances for parking and provision of recharging infrastructure in new building development schemes. Similarly, urban planning regimes that are favourable to EVs and recharging infrastructure will also help to nurture markets.

6.4 Smart Services

The challenge of successfully introducing EVs and accelerating market uptake is encouraging new ways of delivering public services and commercial offerings.

Strong public-private partnerships are proving critical in the implementation of EVs and recharging infrastructure. This reflects the fact that the early markets for these goods are characterised by a need for government support. Accordingly, the task for public authorities is to facilitate the transition to industry-led business models by establishing long-term stable frameworks that incentivise private investments.

Governments and local authorities can also make commitments that demonstrate leadership in promoting markets for EVs. For example, the cities of Stockholm, Copenhagen, and Los Angeles all have clean vehicle procurement policies. Similarly, Nagasaki has instigated a programme that allows private citizens to use electric government cars during weekends.

Municipalities and industry are also working together to ensure that the required skills and services are in place to support the operation of EVs in cities. This includes the provision of the necessary training to vehicle dealers, technicians, manufacturing staff, emergency services and breakdown operatives.

EVs are providing new models for accessing and owning vehicles. For example car sharing

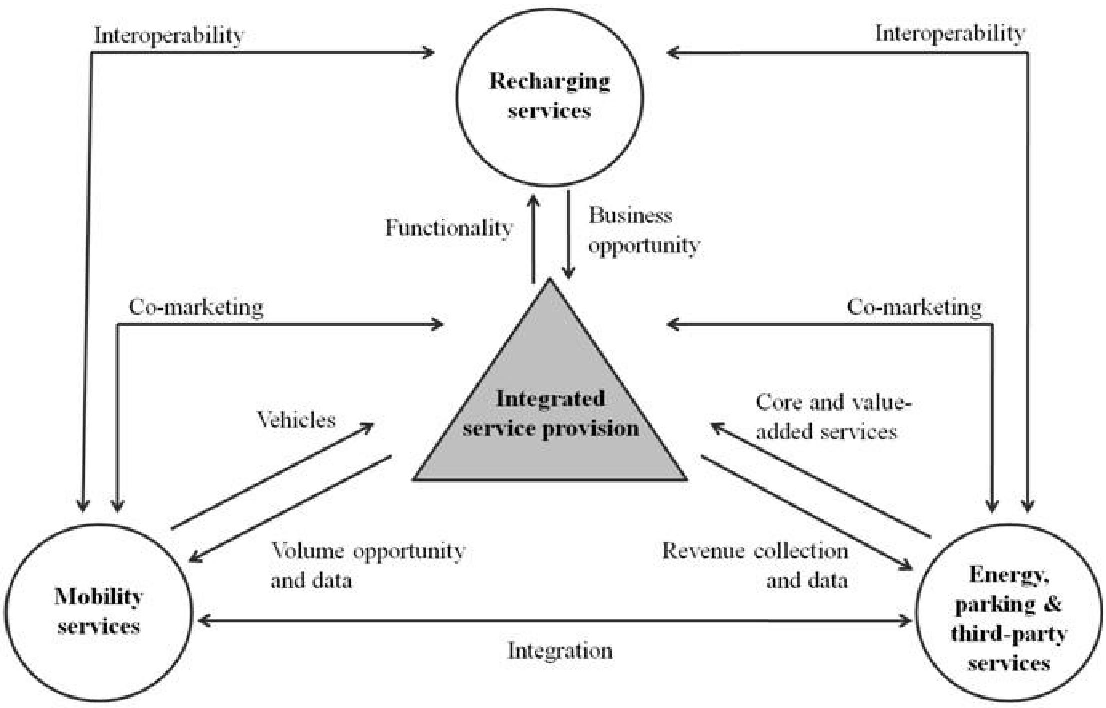

Figure 4: Integrated service models in an EV ecosystem, *based on* [7]

programmes and car clubs provide an excellent platform to grow the market for EVs as part of wider sustainable travel initiatives. Similarly, new service models are emerging from vehicle manufacturers, rental agents and leasing companies which enable customers to access conventional vehicles when they need to make exceptional journeys for which the range or capacity of their EV is not suitable.

Integrated service models will also play a role in overcoming some of the present day market failures associated with EV and recharging infrastructure provision. Fig.4 is an adaptation of a model from the telecoms sector [7] which epitomises the ecosystem concept. In this model partners in a value chain work together to provide a seamless experience for end-users in a way that provides all partners with a fair margin. As shown in Fig.4, this requires the development of technical and commercial collaborative structures.

Another area that will have a key role in nurturing markets for EVs is financial services. Beyond purchase incentives and tax credits, growth will be supported by low-interest loans, leasing models and warranties that provide assurance against concerns such as battery degradation and the residual value of EVs. This is not likely to be in the form of government-led schemes, but more likely driven by banks, vehicle retailers and leasing companies.

It is important to also consider the end of life disposal and waste management of batteries and battery components. This raises a range of economic and environmental imperatives to encourage new second-life applications of batteries and the development of recycling technologies and services.

6.5 Smart Communities

Establishing readiness for mass adoption of EVs requires measures to raise awareness and build confidence amongst the public.

As well as addressing basic issues associated with health and safety in interacting with EVs and recharging equipment, educators are also using the considerable public interest in EVs to promote the science, technology, engineering and maths agenda. While this may appear a relatively short-term gain, long-term technological advances and growth in the markets for EVs will ultimately be driven by these future generations.

Another important reason for EV educational programmes is that mass acceptance of currently available technology will require a degree of behavioural change in areas such as refuelling habits and achievable travel distances. As shown in Fig.5, the requirements of customers will change over time and are likely to be met by advances in technology.

While these behaviour changes are in many ways some of the greatest barriers to mass market penetration of EVs, they also potentially represent

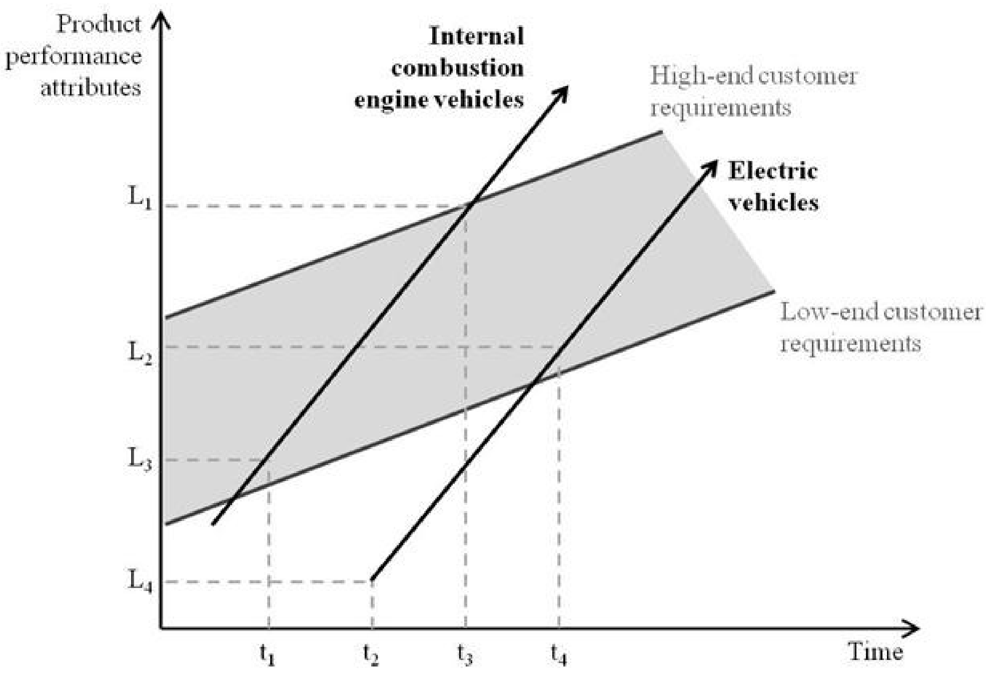

Figure 5: The development of technology and changes in customer requirements, *adapted from* [7 and 8]

the greatest opportunity to accelerate the development of smart cities. This is epitomised by the fact that EVs are proving to be an effective means of engaging the public and media in discussions on highly pertinent subjects such as emissions transport emissions, the carbon footprint of electricity and the cost of energy and fuels. This also encourages reflection on the desirable behaviours in future societies. For example, in many instances it would be preferable for journeys that exceed the driveable range of EVs to be facilitated by public transport. These positive behaviour changes have potential applications and benefits beyond EVs. For example, the challenge of educating consumers to balance the whole-life savings of an EV against the high upfront costs could help facilitate the uptake of other green technologies such as microrenewables. Likewise, an increased awareness of the cost and scale of energy consumption can be used to promote energy efficiency measures. For example, relating energy consumption to the distance that could be driven by an EV is a far more visceral than other more abstract comparisons such as the equivalent number of light bulbs that could be powered.

6.6 Smart Economies

Many governments around the world have identified EV as a sector that offers high potential for growth. The importance of this is heightened by the recent financial and economic crisis has placed economic growth at the forefront of policy decisions.

EVs pilots that have been catalysed by an economic growth agenda have primarily focused on supporting automotive manufacturing and to a lesser extent battery industries. The converse of this is that in many countries and regions where these sectors do not make a notable contribution to gross domestic product, the economic growth potential of EVs has been largely overlooked. While this has not necessarily prevented these countries and regions from implementing initiatives to support EVs, such programmes are usually motivated by climate change, air quality or energy security agendas.

From the breadth of technologies and services identified in this framework, it is apparent that the economic development potential of EVs is not just limited to automotive and battery manufacturing. The examples in the framework make links to sectors such as ITS, public transport, energy generation and management, building technologies, financial services and skills provision. This list is by no means exhaustive, with benefits in seemingly unrelated sectors also emerging. For example the concept of EV tourism is developing, with hotels in North East England installing recharging infrastructure to promote themselves as destinations for EV drivers. Similarly, EV sightseeing tours are in operation in Yokohama.

Nurturing markets for EVs is strongly linked to the concept of green growth, which recognises environmental protection as a driver for global and national economic development and not just an economic burden. Green growth also responds to calls to re-focus societies on achieving a qualitative growth, rather than continuing to measure success based on traditional quantitative economic indicators, such as Gross Domestic Product [9].

7 Conclusion

EVs offer considerable potential to make progress in a variety of wider environmental, societal and economic objectives. The roll out of intelligent infrastructure, the creation of innovative service models and changes in consumer behaviour are all positive transformations that could accelerate the development of smarter cities.

The EV Ecosystems project is working to better understand these opportunities and to shape a global vision on how EVs can create cities that are more intelligently responsive to future green lifestyles.

The policy framework presented in this paper outlines a number of important domains with which EVs interface in cities. This enables a more holistic view of the breadth of opportunities and challenges facing cities and regions in preparing for mass adoption of EVs.

The importance of this future outlook is underlined by the recognition that growth in markets for EVs is by no means certain. While many present day pilots are concerned with establishing the necessary conditions to introduce EVs, it is also essential to develop strategies and interventions to advance to future stages of market maturity.

The costs of climate abatement and the potential for new economic growth should be sufficiently high to motivate governments, cities and industries to ensure progress beyond the initial experimentation stage with EVs. However, there is a danger that future policy frameworks and investment decisions fail to recognise the breadth of opportunity. This is already apparent, as a number of governments and cities have scaled back their EV programmes in recent years on the basis of simple judgements such as short-term contributions to climate change and air quality objectives.

Overcoming the present day failures in markets for EVs will require long-term frameworks that incentivise investments in research, development and commercial offerings. This demands innovative and stimulating policy directions and goals that support the realisation of the full potential of EVs to contribute to economic, environmental and social transformation.

Acknowledgments

The author would like to thank the sponsors and partners in the EV Ecosystems project: Ajuntament de Barcelona; Austrian Institute of Technology; Austrian Federal Ministry for Transport, Innovation and Technology; Electric Vehicles Initiative; eNOVA Strategy Board for Electromobility; German Federal Government; IDAE; Inteli; Siemens; UC Davis; Urban Foresight; and U.S. Department of Energy.

Special thanks to Tom Turrentine at UC Davis for his role as Vice-Operating Agent and continued enthusiasm for this work.

The Executive Committee at the IA-HEV for their input and support.

All of the experts around the world that have attended workshops and shared data with the project.

References

[1] Harte, J., Shireman, B., Burke, A., and Scarlett, L. (2001) *Business as a living system: The value of industrial ecology (a roundtable discussion)*, California Management Review, Vol.43, No.3, Spring 2001, pp.16-25.

[2] Kuhlmann, S. (2001) *Future governance of innovation policy in Europe – three scenarios*, Research Policy, Vol.30, No.6, pp.953-976.

[3] Shipara, P. and Rosenfeld, S. (1996) *An Overview of Technology Diffusion Policies and Programs to Enhance the Technological Absorptive Capabilities of Small and Medium Enterprises*, Background paper prepared for the Organization for Economic Cooperation and Development Directorate for Science, Technology and Industry.

[4] Rogers, E.M. (1983) *Diffusion of Innovations*, Free Press, New York, USA.

[5] Moore, G. (1995) *Crossing the chasm*, Harper Business, New York.

[6] Brown, S., Pyke, D. and Steenhof , P. (2010) *Electric vehicles: The role and Importance of Standards in an Emerging Market*, Energy Policy, vol. 38, pp.3797-3806.

[7] Goffin, K. and Mitchell, R. (2005) *Innovation management: strategy and implementation using the pentathlon framework*, Palgrave MacMillan, Basignstoke, UK.

[8] Christensen, C.M. (1997) *The Innovators Dilema*, Harvard Business School Press, Boston, Mass, USA.

[9] OECD (2009) *Environmental Cooperation in the Context of Green Growth*, Annual Meeting of the Task Force for the Implementation of the Environmental Action Programme, Paris, 15-16 October 2009.

Author

Dr. David Beeton holds two Masters degrees in Engineering and a PhD in Technology Management from University of Cambridge.

As a Director at Urban Foresight, David heads an action-oriented think-and-do-tank that develops strategies and projects for smart cities. This includes leading the global EV Ecosystems task force for IA-HEV and a government-led industry collaboration to advance EV adoption in Scotland.

David was formerly the principal strategist for a major EV programme in North East England. This leveraged investments of over £500 million and established the region as a leading international location for this new industry.