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Systemic innovation and organizational change in the car industry: electric vehicle innovation platforms

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The design and development of Electric Vehicles (EVs) is a complex and distributed process that has led to the creation of large partnerships, the aim of which is to learn and acquire selective technological competencies, including those developed outside the car industry. The introduction of electric vehicles can be described as a collective innovation wherein different actors, such as traditional OEMs, automobile battery producers, utilities, and system integrators, contribute their complementary resources and technologies to work towards common goals and incentives. We argue that the process of integration, coordination and direction of the different strategies and goals of the various organizations involved demands a novel form of organization that combines the scope of learning typical of networks with the coherence of the centralized decision-making typical of the vertical corporation. We identify the innovation platform, which has recently been the focus of numerous studies in the field of innovation, as the appropriate organizational solution to the problem of dynamic coordination.

Collective Innovation, Electric Cars, Industry Structure, Organizational Change, Platforms

1. Introduction

The question of electric vehicles (EV) has resurfaced many times in the history of the car, starting from the early post-WW2 years, but has never made it past the edges of the mainstream.

However, in recent years, macro factors –such as oil price hikes, growing concern about the emission of carbon dioxide into the atmosphere (the main causes of the greenhouse effect and global warming) and, especially, the focus on technological innovations in complementary sectors to the automotive industry (in particular, the significant advances in battery technologies)– have radically changed the picture, sparking new development opportunities for this innovation.

Nevertheless, a number of factors need to be resolved before the technological opportunities translate into economic effectiveness, including battery technology, which has not yet stabilised and, therefore, no standards set, leaving the alternatives unresolved. The cost of the batteries themselves is still too high compared with the lower cost of traditional car batteries. In addition, substantial public investment is needed to promote consumer incentives, support car manufacturing research, and build the infrastructure. The projected scenarios are not convergent. Neither should we discount the competition from technologies alternative to the electric car, starting with innovations to the traditional internal combustion engine. A further element of uncertainty is the very definition of electrical cars, in that we have diverse solutions, from the simple start-and-stop to the totally electric car and the hybrid vehicles in between.

These factors make the introduction of electric cars seem a particularly complex innovation as it demands the coordination of a number of heterogeneous yet complementary factors. These not only call into play the entire automotive sector, but also elements and actors traditionally external to it.

On this subject, we underscore the work of David Teece (1984), in which a radical or “systemic” innovation is defined as a new product or technology that requires changes in different elements inter-connected within the system in which it will be located. Systemic innovations require the development of complementary goods, competencies and innovations in order to maximise profit through their commercialisation. This poses two fundamental problems: 1) the problem of dynamic coordination, i.e. the need to coordinate and integrate complementary competencies in the innovation process; and 2) the problem of minimising the uncertainty linked to the introduction of a complex technology, complex because based on the interdependency of different elements. Furthermore, systemic innovations can trigger enormous difficulties in incumbent systems, determining the success or not of a new-entry company or the redefinition of an entire industrial sector, its structure, and the relations between the actors.

From that perspective, the introduction of the electric car seems to assume the traits of systemic innovation.

This paper, which draws on the theoretical contributions that analyse innovation as a distributed and collective phenomenon, argues that the adoption of the electric car will be determined not only and not so much by the specific technological choices made by the carmakers and battery producers, but above all by the ability to organise and manage the integrated action of a cast of both traditional and new players, (car manufacturers, battery producers, producers of vehicle management systems, transport service management companies, energy distribution companies, energy producers, and governments) through the creation of networks, alliances and coalitions explicitly oriented towards the governance of innovation.

The growth of innovation platforms across a range of industrial sectors recently has attracted the attention of numerous studies of industrial economics and innovation economics (Gawer and Cusumano, 2002; Gawer, 2009a; Gawer, 2009b; Consoli and Patrucco, 2008 and 2011; Patrucco, 2011), which have investigated the nature of these structures and how they influence the evolution of industrial sectors and innovation processes. In fact, it is now acknowledged that the emergence of

platforms has a profound impact on industrial dynamics, creating new forms of competition and laying the foundations for the creation of new relations of inter-organisational cooperation in the framework of innovation processes (Gawer, 2009a).

On that basis, the success of the electric car would depend on the adoption of the most appropriate organisational model, that of a network for innovation, coordinated by key companies that manage the integration of the competencies and technologies of the various players. This model seems to be well exemplified at present by the experience of Better Place.

After the Introduction, the paper is organized as follows: Section 2 sets out the theoretical framework underpinning this work; Section 3 describes the structure and trend of electric cars from both the technological and economic viewpoints; Section 4 outlines the implications for the supply chain; and Section 5 investigates the role of the so-called “complementers”, among which the most relevant for the present analysis is that of the platform leaders such as Better Place. The paper ends with a summary of our conclusions.

2. Organization of collective innovation: from the vertically integrated company to platforms. The theoretical framework

This section examines why the inception and implementation to full potential of a new mobility system –focused on battery-fuelled vehicles and linked to the electricity grid– requires a widely shared vision, opened through the cooperative and integrated action of a myriad actors (McKinsey, 2009; Beaume and Midler, 2009) and the creation of specific innovation networks.

The tradition of industrial economics and economics of innovation in the last century supported the theory of the vertically integrated Fordist company, considered the most efficient organisational model for the production of technological innovation thanks to the benefits from the economies of scale, scope and learning that the vertical integration of R&D activities makes it possible to obtain (Chandler, 1990; Penrose, 1959).

Since the 1990s, however, various factors have emerged that have led to a rapid and radical transformation of the context in which firms compete, raising doubts about the applicability of this model in the new scenario. First, the growing turbulence of the situation (such as, in this case, the greater instability of oil prices and the uncertainty linked to the cost and stability of electric battery technology, as well as that related to the identification of the different segments of demand for electric cars) and the heightening of global competition reduces the efficiency of management and control planning. In other words, it is growing more difficult for the governance of innovation to predict, with a sufficient degree of confidence, the evolution of all the variables, hindering the sensible and rational organization of activities. Second, the greater complexity of innovative dynamics, the acceleration of technological obsolescence, and the significant increase in innovation development costs reduce a company’s level of autonomy. No company alone is able to fully dominate all the technological and organisational competencies needed, nor

is it likely to have the financial resources to develop new knowledge on its own. Third, the expansion of the scientific-technological system is accompanied by an increase in the sources that companies must investigate to seek out new knowledge to use in their innovation operations. In short, the potential number of innovation agents multiplies as public-sector research and corporate R&D laboratories are joined by other actors in the new knowledge production chain, among which science parks, not-for-profit centres, and university and public-sector laboratories linked to intermediate government bodies (regional or supra-national); naturally, that is in addition to innovative start-ups, incubators, and major international research networks (Foray, 2004).

The vertically integrated corporation and its R&D laboratories see their margins of autonomy and self-sufficiency shrink. In particular, large companies lose their prime position as the place par excellence for the production of innovation. In fact, in a complex environment, characterised by continuous changes in the features of the products and production technologies, radical uncertainty and increasingly sophisticated scientific and technological specialisation, the individual company finds it hard to manage all the competencies needed to generate new knowledge using purely the capabilities produced internally.

The scenario outlined above therefore questions the model of the integrated corporation, but also the traditional organisation of innovation frameworks. This implies that the linear and closed model, which saw innovation as a direct and almost automatic effect of investments in R&D and learning-by-doing processes, must be replaced. Not only must the companies develop a structure capable of drawing advantage from the external knowledge available, integrating it effectively with the knowledge produced internally (Chesbrough, Vanhaverbeke and West, 2006), but also the industries and supply chains must reconfigure their boundaries and architectures to benefit the competencies and technologies developed in other sectors (Jacobides, Knudsen, Augier 2006). For example, as shown in the next section, the arrival of battery technology newcomers spurs the car manufacturers to set up joint ventures and vertical as well as horizontal agreements with the aim of minimising the risk of dependency on battery producers.

As a consequence, consensus among innovation scholars recently has grown around the idea that if companies are unable to independently develop sufficient innovation capacity internally, they can implement a variety of solutions that goes from one extreme (vertical integration) to another (the market), transiting a variety of hybrid strategies, forms of strategic alliances, and inter-organisational relations aimed at minimising the costs of external coordination and maximising the creative contribution of each individual company. That theory has opened the door to the analysis of the various forms (lesser or greater) of decentralisation, specialisation and division of innovative labour and production that have appeared after the crisis of the organisational model of the vertically integrated corporation.

This has led a broad thread of studies on the organisation of knowledge and technological innovation to focus on modular systems based on outsourcing and market transactions as the coordination mechanism of the division of labour in innovative activity (Arora, Gambardella and Rullani, 1998; Baldwin and Clark, 1997; Langlois, 2002). When a system is extensive and complex and the

interdependency between the elements and subsystems becomes particularly numerous, coordination through an integrated structure is almost impossible and, as claimed by, for example, Baldwin and Clark (1997) and Langlois (2002), the organisation of production and innovation through modular strategies is the most efficient way to organise and coordinate complex technologies and production systems.

In line with this approach, companies can decide to adopt an integrated or modular organisational structure on the basis of the technologies and competencies that are the foundations for the introduction of innovation: the more the knowledge and technological competencies needed for innovation are varied and interconnected, the more the adoption of a modular architecture and the recourse to formal contracts and market transactions will be efficient. And *vice versa* (Chesbrough and Teece, 1996).

However, the *loose coupling* strategy, as it has been called, does present some limitations. In particular, activities that demand exchanges of complex technological knowledge require the presence of far more rigid, frequent and long-term integration mechanisms than a modular organisation usually manages to guarantee (Schilling, 2009). If the activity demands an intense form of coordination and continuous in time, the development process is conducted more efficiently within a more integrated and hierarchical organisational structure which maintains closer integration between the partners involved.

Further, by definition, complex systems cannot always be broken down into discrete and distinct components as the modular structure suggests (Patrucco, 2011). One of the main characteristics of complexity lies in the recognition that the system cannot be reduced to its individual elements and sub-systems, in that changes in the conduct or the characteristics of a company also determine –through feedback processes deriving from the interaction between the elements– transformations in the other organisations belonging to the system. Lastly, empirical evidence shows that, in tackling choices linked to the organisation of their own innovation activity, companies do not have purely modular or purely integrated solutions to hand. Instead, the characteristics of the two alternatives co-exist and companies are able to use a broad spectrum of inter-organisational solutions in order to combine the advantages of both options (Brusoni and Prencipe, 2001; Consoli and Patrucco, 2011; Zirpoli and Camuffo, 2009).

In this direction, a growing literature has put increasing emphasis on networks as the place of innovation production: the networks facilitate the coordination and integration of complementary technological competencies in contexts characterised by complexity, uncertainty and the dispersion of these competencies between heterogeneous sources, avoiding the costs and inefficiencies of full integration (for example, Powell, 1990; Uzzi, 1997; Burt, 2000; Kogut, 2000; Helper, MacDuffie and Sabel, 2000; Ozman, 2009).

In particular, innovation studies have progressively asserted the idea that inter-organisational links and hybrid forms of integration and modular organisation are the most effective solutions for the management of innovation, in that collaboration aids access to a wide range of complementary technological competencies, representing an opportunity to recombine existing resources and competencies

developed by the individual company in new knowledge. The efficiency of these organisational forms lies, in particular, in the fact that they enable learning and innovation by exploiting the mixture of resources from different companies.

Innovation and the creation of new technological competencies are increasingly seen as a collective and distributed phenomenon, based on a high degree of complementarity between internal R&D investments and the learning of technological resources acquired externally from other companies (for instance, customers, suppliers, and competitors) and from research bodies (e.g., universities, public laboratories, technology transfer centres) (Allen, 1983; Cowan and Jonard, 2003; Patrucco, 2008).

In line with the pioneering contribution of Nelson and Winter (1982), in which economic change is the product of the action of actors who possess idiosyncratic and highly specialised expertise, technological competencies, due to their high level of specialisation and differentiation, therefore are characterised by rather limited degrees of inter-changeability and substitutability, and, thus, high complementarity.

External competencies may differ considerably from those possessed internally by the company (Pisano, 1996) and the implementation of the processes of screening and learning strategies is a prerequisite to access existing external knowledge and to render the exploitation of externalities efficient in the creation of new knowledge and its dissemination within locally-based innovation systems.

On this point, some authors (Cohen and Levinthal, 1989) talk about the 'two faces' of R&D and the importance of investing in internal R&D also to be able to use knowledge arriving from outside. This implies, for instance, that internal R&D activities acquire new functions, extending their role from solely the production of new technological knowledge to the identification and comprehension of the available external knowledge, the selection and integration of the significant portions with internal knowledge in order to produce more complex combinations, and the generation of additional income through the sale of in-house research to others so as to be able, in the same way, to integrate and use it in their own innovation process (Cohen and Levinthal, 1991).

Much of the analysis on the effectiveness of the networks as innovation governance models has focused on the nature of the relations and roles played by the various actors within the networks. In fact, the structure of the network influences the learning and technology curves of companies; in particular, the collaborative relations established within the networks influence the behaviour of the members by creating the conditions for the generation of new research and innovation opportunities.

The analyses concentrated on the respective advantages of the various structures of relations that occur within a network and, in particular, of two contrasting configurations: on the one hand, the networks characterised by strong and abundant ties and, on the other, the networks characterised by structural holes and weak ties.

According to Coleman (1990), for instance, the networks characterised by strong ties would generally be associated with an intense exchange of information, effective mechanisms of transfer of tacit knowledge, and reciprocal trust between partners. Therefore, these links would be more efficient for the exchange and communication of complex knowledge because they would promote the

establishment of more efficient cooperative attitudes thanks to the repeated exchanges and a balanced distribution of power within the network. In contrast, some authors claim that the networks characterised by weak connections and by structural holes that play a role as broker, directing and coordinating the knowledge flows between companies or groups of companies not directly linked to each other, would be more efficient solutions due to the advantages stemming from a partially hierarchical organisational form (Burt, 1992).

The empirical evidence demonstrates that both the configurations are correlated to an improvement in the innovative performances of companies and it is in exactly this context that the concept of innovation platforms expresses its full interpretive potential. Innovation platforms are characterised by system integrators or platform leaders which through a hierarchical structure govern and coordinate the interactions between organisations not directly connected with each other.

In this sense, companies that act as system integrators represent specific forms of structural holes at the centre of the flows of different portions of knowledge that form the base of complex technological innovations.

On the other hand, the growing division of labour produced by the complexity of both products and knowledge generates an increase in the number of components and types of knowledge required to fine-tune the final product. Abundant links in this context are often necessary to obtain specific complementary competencies and share the relevant knowledge with other companies in the system. Direct collaboration –i.e. not mediated by structural holes– for instance, between two specialist suppliers can therefore be necessary to co-define a new component or sub-system of a complex product. In this case, the network assumes some of the properties of the flat and dense structures described by Coleman (1990).

Innovation platforms are specific governance forms through which economic players and their organisations acquire and coordinate innovative capabilities and new knowledge (Patrucco, 2011). The notion of platform expresses the view that innovation occurs efficiently and successfully when partnerships are implemented based on the convergence of incentives and structured complementarity of the competencies of a variety of heterogeneous actors, so as to grow the cohesion of the group and organise the intrinsic complexity of the system around a common purpose and shared goals.

Efficient platforms emerge when the various incentives and complementary capabilities of a multitude of heterogeneous network actors are organised and aligned so as to ensure the cohesion of the network and the coordination (managed through a complex network of high-quality interactions) of the division of technological knowledge and labour in the innovation process.

Empirical evidence shows the emergence of this type of coordination structure in many sectors in which innovation and the production of new technological competencies are, to a growing extent, the effect of integrating diverse and complementary competencies distributed and scattered between specialised and heterogeneous actors (such as the automotive, banking, electronics and software sectors). In fact, one of the key points of the rationale that underpins the creation of platforms is the maximisation of the variety of contributions from mixed sources of

knowledge, combined however with the maintenance of global coherence through a hierarchical structure (Consoli and Patrucco, 2011).

In this regard, the platforms represent a significant organisational innovation, different to the integrated company, the market and the networks themselves. The platforms appear rather as a new and specific form of governance of knowledge that emerges as an effect of the dynamics of complex systems (Consoli and Patrucco, 2011). In particular, they can be defined as hierarchical networks, i.e. as networks in which the interactions do not emerge and evolve spontaneously, as in the traditional literature on the industrial districts or as hypothesised by complexity theory, but in which the key nodes (the companies) perform a guiding role for the behaviour of the other actors, thus influencing and directing the behaviour and the evolution of the system as a whole (Consoli and Patrucco, 2008).

What distinguishes these organisational forms is the active search for complementarity (compared to mere agglomeration) between different activities. In other words, the innovation platforms are structured and designed in line with specific and predetermined innovation objectives (contrary to spontaneous phenomena, such as the networks) and, as mentioned earlier, in which the platform leaders play their role.

A framework in which, it has been recently highlighted, the platform leaders play a crucial role in the success and efficiency of the innovation process. Concepts like *architectural knowledge* (Henderson and Clark, 1990), *architectural capability* (Jacobides, 2006), and *system integrators* (Prencipe, Davies and Hobday, 2003) were introduced recently to describe precisely that decisive capacity, possessed by the network leaders, to coordinate and manage the work of complex organisations and, more specifically, to combine the elements typical of the integrated models (such as authority and control) with the characteristics typical of modularity (such as a sufficient degree of openness) in order to select the significant competencies and knowledge to include in the network (Consoli and Patrucco, 2011).

As will be discussed later, the business model pioneered by Better Place, which combines elements of hierarchical coordination with elements of the decentralisation of innovative and production capabilities and activities, has the potential to be configured as an innovation platform and positioned at the centre of the innovation process –in this case, the introduction of electric cars– in which innovation is the result of collective processes and activities and where new players take position at the centre of the innovation process both as suppliers and as integrators.

The arrival of newcomers from other sectors entails not only the introduction of new competencies and technologies to the core sector, but also the redefinition of roles and power relations within it. At this point, the analysis of the supply chain becomes fundamental to understanding how the introduction of electric technology can change the architecture of the relations between the OEMs and the various supplier levels and, consequently, the structure of the collaborative relations between the different actors, which, as we have noted, is a decisive factor of success in the introduction of new technology.

3. The electric car, an eternally emerging technology: characteristics and dynamics

As underscored by some recent studies (Beaume, Midler, 2009; Frery, 2000; Kirsch 2000; Hoyer, 2008), research on electric and hybrid vehicles is nothing new in the transport sector, but has resurfaced many times in the history of the automotive market, so often, in fact, that it represents a perfect example of a ‘technologie éternellement émergente’ (Frery, 2000). A technology whose development has been discontinuous, characterised by great acceleration at the beginning of the 20th century and repeated stops and starts compared with expectations.

The undisputed success of the internal combustion engine led to the virtual abandonment of EV research until the 1970s, when the emergence of environmental issues and the 1973 oil crisis brought the energy question to the forefront of public attention. From the mid-1970s to the mid-1990s, EVs enjoyed successive waves of enthusiasm, to such an extent that more than one authoritative study forecast as highly probable the development of a vast market that would grow so fast that it would take only a few years to grab a share of between 10% and 25% of the car market¹. However, things have turned out completely different, with two consultancy firms indicating in 2010 that the market share of completely electric and hybrid cars would not rise above 1.6% (Analyst Note of Autofacts)² or 2.2% (J.D. Power)³.

In fact, the production of forecasts still continues today with diverging results depending on different scenarios adopted (Figure 1).

Figure 1. Market forecasts for electric cars⁴

SOURCE	2020	2025	2050
J. D. Power & Associates, 2011*	5,50%		
Bain & Company, 2010 **			
Fundamental change	80%		
Basic scenario	50%		
Little change	<20%		
Boston Consulting Group, 2009			
Slowdown	12%		
Steady pace	28%		
Acceleration	45%		
Oliver Wyman, 2009		42%	

¹ An analysis of the various estimates of the 1990s is contained in Beaume, Midler (2009).

² http://www.autofacts.com/content/an/PwC_Autofacts_Electric_Vehicle_Outlook_Nov_10.pdf

³ <http://www.prnewswire.com/news-releases/jd-power-and-associates-reports-future-global-market-demand-for-hybrid-and-battery-electric-vehicles-may-be-over-hyped-wild-card-is-china-105857988.html>

⁴ EV: Electric Vehicle; PHEV: Plug In Electric Vehicle (electric cars that can be recharged from the electricity grid).

Roland Berger, 2011			
	Europe	48%	
	USA	42%	
McKinsey & Company, 2010			
	Conventional		40%
	Electric vehicle dominated		95%

Source: Fairley (2011); Matthies, Stricker, Traenckner (2010)

To further complicate the picture, the range of electric vehicles is fairly wide as, more than a product, what lies ahead is an ‘electrification path’ (BCG, 2009). At one end, we have the vehicles with limited savings in terms of emissions and lower use of electricity, while at the other there are those that offer significant increases in efficiency and lower levels of emissions. The vehicles in this segment present increasingly higher costs because the higher the use of electricity, the higher the battery power required, thus raising its cost.

EVs can be categorised as follows:

Hybrid-electric vehicles (HEVs) combine an internal combustion engine with a supplementary electric engine. The first is generally the main system and works at higher speeds, while the electric engine is used to power the vehicle in the city and over short distances (the example is the first series of the Toyota Prius).

Plug-in hybrid electric vehicles (PHEVs) and **range-extended hybrid vehicles** (such as the new Toyota Prius and the Chevrolet Volt from General Motors, respectively) are **hybrid vehicles** with **rechargeable batteries** that can be restored to full charge by connecting a plug to an external **electric power** source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle and of an **all-electric vehicle**, having a **plug** to connect to the **electrical grid**.

Fully EVs or battery electric vehicles (BEVs), such as the Mitsubishi i-MiEV and the Nissan Leaf, soon to be released) do not possess on-board electricity generation devices so the battery can be recharged only by connecting the vehicle to a socket (and so to the electricity grid) or by changing the discharged battery with a fully charged one.

In such a scenario of technological variety, adopting a prudent approach (PFA, 2010), the forecast for 2020 indicates that: around 95%-98% of vehicles will still continue to be fitted with internal combustion engines, of which a non-negligible share will be equipped with a certain degree of hybridisation; the “full hybrids” will remain essentially limited to the high-range vehicles; and the adoption of fully electric vehicles will be concentrated, thanks to public support, in mini local markets, such as cities. Therefore, it is clear that the different types of electric cars could co-exist in the market alongside traditional internal combustion vehicles over the longer term: **massive conversion to pure electric cars, the only way to achieve a true turning point in the conception of the architecture of the car product, is credibly imaginable only in the long term (50 years) (PFA, 2010; BCG 2010).**

If, in percentage terms, the electrification process seems to be a relatively limited phenomenon, in the medium term, its dimensions in absolute terms should not be disregarded: using the forecasts shown on the horizontal axis of Fig. 1, the forecast

for 2020 indicates more than 87 million vehicles sold (cars⁵ and other vehicles) compared with just short of 50 million in 2010 (of which, 44.7 million exclusively cars), which works out to an increase of 74%, or 37 million in absolute values (about 26 million exclusively cars). Therefore the number of electric cars (including hybrid and mild hybrid cars) could range from 7 million to 21 million, leaving room for 50 million or 64 million traditional cars.

If feasible, those estimates would effectively translate into a co-existence of technologies but without any heavy crowding-out effects, given the substantial growth of the market as a whole. This dynamic is also significant for the supply chain, in particular for the role of components suppliers: the change of the technological paradigm does not seem to have significant effects on the components manufacturers in the short to medium term.

In a nutshell, the success of the introduction of new electric vehicles and the pace of their adoption will depend on a number of interdependent technological, institutional, and social factors, such as the elasticity of demand, the distribution reach of recharging infrastructures, the achievement of critical production capacity, the form of the learning curves of battery producers, the creation of market niches, and the role of governments (Hensley, Knupfer and Pinner, 2009).

Nevertheless, the decisive element in the various analyses seems to be the need to develop networks of the diverse players (incumbents and newcomers), which reflects one of the four conditions identified by Freyssenet (2011) for the development, in the historical sense, of the automotive industry. This means the formation of coalitions and alliances of diverse actors and organisations in order to tackle uncertainty and reach a specific solution to a given problem.

4. The supply chain

The forecasts for the timing and size of the electric car market also influence the components manufacturers and all the other complementary actors involved in the industry, such as the suppliers of energy and services, indicating for each of them opportunities and risks (Figure 2).

Figure 2. Opportunities and risks along the value chain

	Energy Delivery	Conversion and Propulsion Systems	Services
Value gains	<ul style="list-style-type: none"> • Incremental electricity and charge-point-sales • Capital investment avoidance 	<ul style="list-style-type: none"> • Sales of EV cells and packs 	<ul style="list-style-type: none"> • New service/content cannot co-branding • Revenue white spaces
Companies with Opportunities	<ul style="list-style-type: none"> • Utilities • Charge hardware and software providers 	<ul style="list-style-type: none"> • EV-based suppliers • Battery suppliers • OEMs 	<ul style="list-style-type: none"> • Telecom • E-mobility service providers • Municipalities
Value Losses	<ul style="list-style-type: none"> • Reduced gasoline 	<ul style="list-style-type: none"> • Technology 	<ul style="list-style-type: none"> • Reduced vehicle

⁵ According to the J.D. Power estimate cited earlier, car sales alone could be almost 71 million.

	sales • Underutilized infrastructure	obsolescence • Underutilized ICE assets	service demand • Underutilized service assets
Companies at Risk	• Oil companies • Fuel distribution companies	• ICE-based suppliers • Traditional OEMs	• ICE-based services

Source: Hazimeh, Tweadey and Chwalik (2010)

The effects on the car electrification supply chain can be examined from two perspectives, both of which put the issue of networks and collaboration at the centre.

4.1. Long-term view with the arrival of newcomers

In the long term, the centre of attention will be the battery, a decisive component in the adoption of these vehicles, given that it accounts for more than one-third of the vehicle cost and a significant portion of the cost difference between electric and traditional cars (BCG, 2010). According to the BCG (2010), the current estimated cost to car manufacturers of a lithium ion battery pack of the NCA type (nickel, cobalt, aluminium) swings between US\$1,000 and US\$1,200 per kWh, which, multiplied by 15kWh, the power that an average car battery must generate, works out to a unit cost of around \$16,000. The United States Advanced Battery Consortium has set a target cost of \$250 per kWh that can not be reached by 2020 without radical innovation in battery technology (BCG, 2010).

In addition to cost, the batteries also suffer from a technology issue. While the lithium ion battery is touted as the long-term winner, this same technology offers different alternatives and none of these, either at present or in the shorter term, appears dominant in the six dimensions that characterise the batteries themselves as a whole⁶. In fact, without a significant leap in battery technology it is unlikely that fully electric vehicles will be available for the mass market by 2020 (BCG 2010, page 5). In addition to which, “within the technical community there is still considerable doubt as to whether the new batteries will match performance expectations over the entire life of the vehicle” (Barkenbus 2009, page 404).

As a result, the car manufacturers, who have no intention of becoming fully dependent on battery makers, stipulate agreements to control both the development of the technology and production operations. Alliances and joint ventures give car manufacturers exclusive access to the know-how, technology and production capabilities of the battery suppliers, enabling them to differentiate their vehicles on the basis of the battery technology. However, that advantage is accompanied by the risk of restricting the ability to react quickly to the results achieved by other battery producers and also to limit the scale effects.

But the alliances also involve battery producers and first-tier suppliers, a type of collaboration that could grow in the medium term according to a BCG analysis (2010); the components manufacturers would then have to get to grips with the fact that EV cost control would shift to the battery manufacturers, although they could still play a specialist role in the car integration process. For the car producers, this

⁶ Safety, duration - such as the number of charging and recharging cycles - performance, energy stored, specific power and costs (BCG 2010).

trend gives them less control over battery technology and knowledge but offers two benefits: the achievement of economies of scale and a reduced transition cost should new alternative technologies emerge. Advantages that would be enhanced by the standardisation of battery technology.

4.2. Medium-term view on the transition to the future

While the adoption of the electric car is not a short-term issue (it goes beyond 2020), the electrification of vehicles will be an ineluctable change in the medium to long term. If it is believed that the transition cannot be an exclusively spontaneous process between the companies involved, the role of governments becomes crucial as the organising element of transition itself, with action to support the building of a supply chain for electric vehicles.

Many countries have moved in this direction, but the most interesting case is France, where the government is one of the few that, after having assumed the intermediate hypothesis (the most probable evolution) (PFA 2010), has explicitly set the goal of building a supply chain for the electric car, launching a project defined PFA (Plateforme de la Filière Automobile) in 2009 with the mission to:

- enhance the potential for the improvement of engines, suggesting continued support to the competitiveness of France's diesel supply chain, but also the launch a petrol supply chain along with a major national project to develop a small universal engine with the possibility of being hybridised and a consumption rate of 2 to 3 litres per 100 km;
- create a French supply chain for the electric and hybrid car, positioned on technological solutions already defined for 2014-2015 but with the objective of widening their perimeters to new technologies, such as heat management (30% to 50% of the range of an electric vehicle is influenced by air-conditioning and heating), braking with energy recovery (potential to double the range), and the development of auxiliary low-consumption functions. Other initiatives for the electric supply chain include: structuring university and laboratory competencies in electronics and electromagnetism; developing batteries for system integration; and developing the aggregation of French competencies in a European context.

The development of the French supply chain also will depend on the initiatives that can be set in motion to give an economically significant dimension to the production of electric vehicles. This is the direction that 20 private and public companies⁷ have decided to take to establish a grouping for the purchase of 50,000 electric vehicles starting 2011, but which could reach 100,000 if other players join the scheme.

As to the individual components manufacturers, these will need to expand their current competencies, especially to cover entire systems and thus optimise costs and functions. While large companies can expand through internal growth, medium-sized firms need to establish networks of companies to create and manage a system of competencies to develop integrated systems and integrated products (Kampker, Burggraf and Deutskens, 2010).

5. The role of the complementary actors

As noted in the introduction, the success of the electric car requires the contribution of other players outside the automotive supply chain, such as electricity producers and service providers. For the purposes of this paper, the aim of which is

⁷ ADP, Air France, Areva, Bouygues, EDF, ERDF, Eiffage, France Telecom, GDF Suez, Suez Environnement, GRT Gaz, GrDF, La Poste, RATP, SAUR, SNCF, SPIE, UGAP, Vinci, Véolia.

to investigate the organizational implications of technological change, we focus here on the latter.

As already mentioned, the cost of the batteries is an issue that does not concern solely the OEMs, but has big impact on the purchaser of this type of vehicle, given that the high cost difference depends precisely on the cost of the batteries. A constraint that would lead to a new type of ownership and a new business model for companies through a new type of company, whereby instead of buying the whole vehicle, the customer would purchase solely the car without the battery and pay for this latter only through actual consumption, or what is called the 'pay-per-mile' system. In this case, the consumers and carmakers would be joined by a new actor, the company that manages the recharging and replacement of the batteries. The adoption of this radically new business model is defined as a disruptive strategy (Barkenbus, 2009) that can more easily be proposed by newcomers rather than incumbents such as the car manufacturers. Indeed, such a model would be able to modify/alter the preferences of consumers, presenting a more appealing range of electric cars (for example, lower price, comfort and ease of use). In practice, this is the model proposed by Better Place and adopted by Renault for pilot tests in Israel and Denmark. According to that model, the vehicle is purchased separately from the battery, the ownership of which latter is transferred to an electric car network operator (such as Better Place), thus eliminating consumer concern about the battery's cost and lifecycle.

5.1. Better Place⁸

Just as the electric car model comes from afar, so does the business model adopted by Better Place. The Better Place model has found application in some countries, first in Israel and Denmark, but also in Australia, California, Portugal, Hawaii, Ontario, and Tokyo. In the case of Israel, in 2008 the Israeli government, together with Renault-Nissan and Better Place, decided to launch a major project to distribute a cheap and ecological electric car that would be easy to drive and recharge, thus becoming the first country in the world to commit itself to a fully electric car project with the priority goal of eliminating its dependence on oil.

The factors that make Israel a true case study are:

- its small size (250 km in length, excluding the Negev desert), which makes it suitable for the range of electric vehicles;
- a population concentrated in the large cities (in particular, Tel Aviv). Most of the country's drivers (90%) travel less than 70 km per day and none of the towns are more than 150 km apart. Most of the journeys are essentially urban; and
- it has vast sources of electricity, thanks to renewable energy, especially solar power.

The role of Better Place is to invest in the relative infrastructure: recharging points (for at least the part-recharging of batteries) and service stations where the batteries can either be replaced in a few minutes or completely recharged in 4 or 6 hours. The main distinction is the separate ownership of the electric vehicle and the battery, which latter is owned exclusively by the infrastructure management company (i.e., Better Place) for several reasons (CDS 2009): i) the development of the batteries is part of a short innovation cycle that could create consumer uncertainty. Therefore, keeping the car purchase separate from the battery purchase

⁸ A history of the company can be found at <http://www.betterplace.com/>.

would eliminate the question of what would happen in the event of advances in battery technology; ii) it is the only way to lower the vehicle purchase cost; and iii) the range and reliability of the vehicle can be improved by merely changing the battery.

The model's originality lies in the public-private partnership, or what has been defined "collaborative innovation" (CDS 2009) as a number of actors make their contribution, specifically:

- the Israeli government offers tax breaks to consumers and helps to make the investment appealing to the partners by supporting research;
- Renault runs the technical development side and provides the electric vehicle;
- Better Place (i.e. the mobility operator) develops a network of battery recharging stations and a network of battery replacement stations thanks to various sources of finance;
- public and private companies have stipulated contracts with Better Place for the conversion of their fleets to electric vehicles and for the installation of an adequate infrastructure network (for example, the Municipality of Jerusalem and Israeli Railways are responsible for the installation of recharging stations in the capital and close to the main railway stations); and
- most Israeli citizens are open to buying electric cars.

That is the project on paper but a number of practical hurdles remain, including the air-conditioning of the vehicle and the need for supplementary energy when the batteries have a limited charge, the infrastructure network, and the unpredictable times to run the tests and to adapt to the constraints.

6. Concluding remarks

The paper describes the development of the electric car as a complex and distributed innovation requiring the interaction of a variety of diverse and interdependent factors.

It argues that the successful governance of these factors, and therefore the success of the introduction and deployment of electric cars, requires the coordination of a diverse cast of complementary players, not only internal to the traditional auto industry (i.e., carmakers, suppliers), but also external (i.e. newcomers, such as producers of batteries from the electronics sectors, electricity suppliers, and the public sector).

The paper indicates the notion of innovation platforms as the appropriate organizational form for the coordination of such a diverse conglomeration of resources and actors. Innovation platforms combine the benefits of large coalitions, implemented to promote mutual learning and the acquisition of technological and productive competencies sourced externally, with those of centralized decision-making. Indeed, some elements of a hierarchy characterize such models since some direction is required in order to both guarantee the cohesion of the network and the convergence of the complex system of goals, incentives and interactions typical of such articulated innovation processes, not least the development of electric cars. The experience of Better Place has been identified as an original application of the notion of innovation platform to the introduction of electric vehicles.

Clearly, much more research needs to be done to enhance our understanding of the implications for the car industry of the potential introduction of alternative technologies. Research topics such as the characteristics and dynamics of the process of technological standardization; the role and methods through which

national and supra-national government institutions can support the development and adoption of new engine technologies; and the effect that technological change has on the industry structure and dynamics, which are beyond the scope of this paper, are all worthy of dedicated investigation.

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