FROM TECHNOLOGY COMPETITION TO REINVENTING INDIVIDUAL MOBILITY FOR A SUSTAINABLE FUTURE: CHALLENGES FOR NEW DESIGN STRATEGIES FOR ELECTRIC VEHICLE

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FROM TECHNOLOGY COMPETITION TO REINVENTING INDIVIDUAL MOBILITY FOR A SUSTAINABLE FUTURE: CHALLENGES FOR NEW DESIGN STRATEGIES FOR ELECTRIC VEHICLE

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[DRAFT VERSION]

Emissions reduction constraints as well as petrol costs create new opportunities for radical innovations in powertrain solutions for automobiles. In this paper, we focus on the on-going revival of full battery electric vehicles (EV). Our analysis is drawn in two axes.

First, we analyse of the on-going context for such EV. As electricity is surely not a new option for automobile industry, we study the past attempts that failed, and show that it is possible to highlight some conditions for a future success and to see why there is nowadays a new window of opportunity for a large scale roll-out of EV. Our reasoning is based both on market evolution as well as technological evolutions. The recent developments around EV suggest that many of the conditions for a successful tidal wave are about to be combined.

Second, we characterize the innovation & design strategy that an OEM needs to implement in order to turn this opportunity into a profitable competitive advantage:

- ✓ Innovation strategy has to expand the scope of design dimensions from electrification of Internal Combustion Engine (ICE) vehicles to the complete redefinition of a specific electric product solution. Beyond the product scope, we will see that electric mobility services can provide an efficient enabler to overcome the operational and maintenance pitfalls of electric solutions.
- ✓ Marketing strategy also needs to dramatically revise the classical auto marketing approach, as electric mobility will require new behaviours from end users as well as favourable regulations and infrastructures from local authorities.

- ✓ Development processes cannot rely only on the traditional automotive ecosystem, because many competencies required for EV have to be created during the development process. On going EV projects will need a deep rethinking of design system to acquire the new competencies

In this paper, we will discuss first outputs from a long term (4 years) action-research launched at the end of 2007. This research is done at an OEM committed to launch a full range of EV, and which, as a consequence, already faces all the challenges related to such a radical innovation.

1 Introduction

In the automotive history, Electric Vehicle (EV) has been seen as an option for more than a century but lost the competition for mass production of automobiles at the beginning of the 20th century. Since then, several attempts to revive EV have been made, but none of them has succeeded. Thus, we first discuss the history of EV and the several attempts to introduce these vehicles all along the 20th century (§1). We then show that these previous trials, as for example PSA important involvement in the 1990's, are a valuable source of knowledge, to understand the conditions for a credible take-off of EV markets (§2) and so to understand whether the new wave of enthusiasm surrounding EV is somewhat different from the past.

These conditions deal first with the global context of auto industry and mobility. We will see that some important bottlenecks have dramatically diminished if not disappeared in the early 21 century, giving a more favourable context for EV strategies. We will point out these challenges and discuss them on the case our research is focusing on: the recent initiative launched by Renault (§3). We then discuss some preliminary findings that can be derived from the research, regarding new practices for managing innovation aiming at sustainable development.

The paper is based on an-going research on EV at CRG initiated at the end of 2007.

2 Electric vehicles: a dream lasting more than 100 years

Electric vehicle is not at all a new option for the automotive industry. In fact, EVs were designed at the very beginning of automotive history, but they have never been mass-marketed. Nevertheless the very numerous attempts to roll-out electric vehicles are a rich source of knowledge that we briefly sum up.

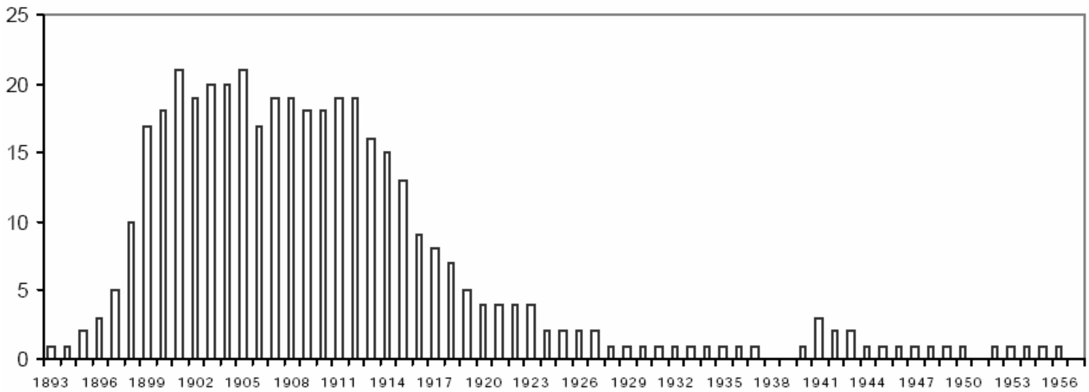
2.1 EV failed to catch the original burst of emerging auto industry

EV is maybe one of the best examples "eternally emerging" technology (Fréry, 2000). It has been dreamt by men for more than a century. The very first examples of EV can be found as early as the middle of 19th century, and EV had a very rich history at the end of the 19th century.

For example, the first time a vehicle exceeded the 100km/h speed threshold was an EV, called la *Jamais Contente*. This torpedo-like vehicle realized this record in 1899, driven by Camille Jentzy (see picture 1).

Picture 1 : *la Jamais Contente*

Actually, there were at the end of the 19th century many car manufacturers that built electric vehicles. The graph below represents the number of OEMs producing EVs between 1893 and 1956:



Graph 1: Number of EV OEMs, 1893-1956 (Frery, 2000)

At the end of the 19th century, there has been a tough competition between several types technologies for automobile: electric vehicles, Internal Combustion Engine (ICE) vehicles, steam powered vehicles and many other different concepts (fuel cell, compressed air…).

The number of EV manufacturers increased until the beginning of the 20th century. But, just before World War I, this growth was brutally stopped for several reasons:

- ✓ EV did not benefit from mass production economies of scale: although the ICE vehicle began its large diffusion at the beginning of the 20th century, thanks to the Ford T (180 000 produced in 1913), electric vehicles have never been mass produced (6 000 EV produced in the United Stated in 1913)
- ✓ EV lost at the beginning of the 20th century one of its main competitive advantages with respect to ICE vehicles: in 1911, the electric starter was developed by Charles Kettering, and sold to Cadillac as soon as 1912.

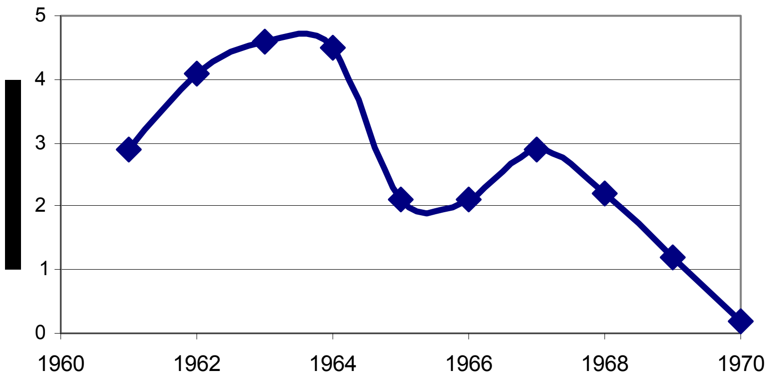
So, at the beginning of the 20th century, EV began its big decline: it had lost, from the end-user point of view its main advantage, it was still expensive as it did not benefit from economies of scale, and its autonomy and performances (time to refuel, dynamic performances…) were definitely inferior to ICE vehicles. It is interesting to note that a Belgian engineer, Piepper, who may have understood before others the inevitable decline, designed and showed in 1899 the first hybrid vehicle at the Paris show (Griset and Larroque, 2006). 300 hybrid cars have then been produced by Porsche and several manufacturers in the US tried to promote this type of vehicle until the late 10s. Rauch and Lang will produce as many as 1000 vehicles a year at this period, which was definitely considered as “craftsmanship” by the standards of automotive industry at that time. Nevertheless this shows that the different possibilities for powertrain (hybrid, full electric, or internal combustion) were all imagined and tested at the very beginning of automotive history.

At the end of the 20s, hybrid and electric vehicles had nearly disappeared. ICE had become the standard of the automotive industry, and nearly all the OEMs were focusing on this dominant design. But this does not mean at all that EV disappeared from the minds of men during the 20^{th} century.

2.2 EV revivals: context opportunities for disruptive EV but disruptive failures

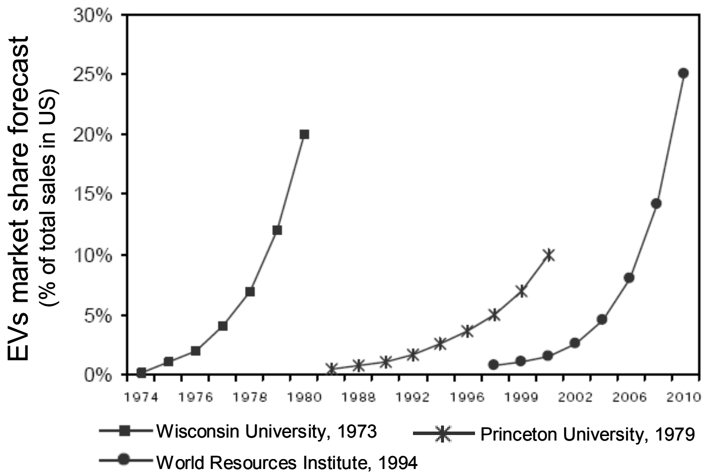
One could think the history of EV to have been rather similar to many other failed technological options: a phase of emergence, characterized by a competition with a rival option, and then a fall in the box of the forgotten technologies. From this point of view, EV is very different because men, both engineers from automotive industry, policy makers, and ordinary citizens have continued to dream about EV revival, even after the failed attempt to mass-market then at the beginning of the 20^{th} century. Several periods of the second half of 20^{th} century have witnessed new waves of enthusiasm for EV. Describing them in details would be too long but we can nevertheless show that actually, there has been a periodical enthusiasm for EV.

At the beginning of the 60s, fuel cells were thought to be very promising, and the enthusiasm was kept alive by the community of researchers. Fuel cells were seen as the good way to store energy for EVs, instead of more traditional batteries (at that time, fuel cells were competing only with lead batteries). These possibilities explain why huge investments in research for fuel cells were done at that time. Several studies from the late 70s, see (Callon, 1980) or (Nicolon, 1977), show that the idea of EVs was strongly supported in the 60s. The data on public funding allocated by the French State on fuel cells research illustrate the point (see graph 2, amounts are in millions of francs, 1 million of francs at that time represented the equivalent of 200 times the typical annual income of a worker)



Graph 2: Research funds by French State on Fuel Cells (1961 to 1970)

In the 70s the 2 oil crises forced industrialised countries to stimulate energy savings. That is why EVs tended to rebirth, and appear as an interesting option for transportation. Between the mid-70s until the mid-90s, there have been several periods of enthusiasm for EVs in the automotive industry. One indicator of these waves of enthusiasm are the rather similar projections made by 3 American institutions, which made different studies at different times between 1973 and 1993. These studies made in the US were assessing the potential future market of EV in the automotive industry (Fréry, 2000).



Graph 3 : examples of 3 studies on the introduction of EVs (1973, 1979, 1994)

These data illustrate that at different periods of time during the 2nd half of the 20th century, there have been many serious scenarios predicting a higly probable mass-marketed for EVs. Other data (Griset and Larroque, 2006) from other countries, show that same projections were made at these periods in several countries.

These different periods of "excitement" over the EV all had rational foundations: during the early 70s as well as the early 80s, because of the high price of crude oil, many countries looked for alternatives. As the nuclear power generation was developed at that time, the alternative proposed by EV made sense.

During the 90s, EV also created a lot of hope because several countries had credible plans to introduce mass marketed EV: among them, France and also the Californian state could have been the place of a first roll-out of EV. In France, PSA and Renault introduced several EV models, which were adaptations of their ICE vehicles. As an example, PSA sold more than 10000 Peugeot 106 and Citroën Saxo, which were launched on the market in 1995. As their commercial penetration proved to be low, they decided to abandon the EV at the very beginning of the 21st century. In California, the result ended to be the same, but not for the same reason: in 1990, Californian state created a legislation that would have made it compulsory for car manufacturers to sell at least 2% of Zero Emission Vehicles by 1997 (this percentage would have increased to 15% in 2003). But, thanks to intense lobbying by OEMs (Pilkington and Dyerson, 2004), the mandate was gradually reduced, until it finally disappeared in 1998.

One has to acknowledge that at the beginning of the 21th century, the EV had not a very positive reputation: it could be seen as a technical option that has been replaced by thermal vehicles a century ago, and that, thanks to several groups of companies, states had been regularly revived at different periods of the 20th century, but never successfully.

3 Lessons learnt: strategies for EV successful development

As we noted in the last §, EV history is made of a succession of trials to deploy EV on a mass-scale. All these attempts have failed not for one single and obvious reason, but mainly because there are some hard-points that have not been solved in the past.

1. Cost of EV and energy storage technologies
2. The ICE/EV product performance confrontation
3. Dominant design for electric mobility
4. Project scope: from EV product to EV mobility service
5. The Business Model of an EV roll-out

3.1 Cost of EV and energy storage technologies

Cost is obviously one of the main challenges for EV roll-out. In effect, EVs need many components that would be developed specifically for EV: all the components related to the engine, the related electronics are part of the challenge, but the most important one that emerged in the past is certainly the battery.

The battery is the most challenging one for a couple of reasons, as it was already acknowledged more than 10 years ago, at the beginning of the last attempt to introduce electric vehicles "The Achilles heel of the EV has always been the battery" (TheEconomist, 1997). First of all, automotive industry could not, until the 90s, hope for some technology transfer because no other industrial sector was pulling for the development of high-energy density and big size batteries. So the only battery technology that was available until the 80s was the battery based on lead acid. Even if cost competitive, the lead acid batteries have never allowed to design cars with satisfying autonomies (the autonomy was always less than 50km). But this was the only mass-marketed technology, because smaller lead batteries were used in each ICE vehicle.

Since the 90s, the context has evolved, not because of EVs, but mainly because a new type of portable consumer electronic devices has been developed and has required the development of high energy density batteries, and also because the market of Hybrid Vehicles has been created and has pulled the development of new automotive batteries with high density power.

3.2 The ICE/EV product performance confrontation

Rich EV history has shown that comparing the performance structure of EV with the typical criteria of ICE vehicles would always advantage the ICE engine. This is a very classical situation in the case of disruptive technologies (Bower and Christensen, 1995).

Thus an attempt to introduce EVs should rest strongly on the performance parameters that favour EV in front of ICE vehicles:

- ✓ collective values: EV has a collective value for the environment, even if one user cannot benefit from it directly. But the individual level, it may be more rational to buy an ICE instead of an EV in the case there are no massive public incentives for EVs
- ✓ new benefits for the end-user: its is more silent, it is easier to drive (no gearbox for example), it has a constant torque.

In the past, the attempts to introduce EVs have failed to displace the performance confrontation from indicators favouring ICE vehicles to indicators favouring EVs. To sum up, past attempts have failed to design a "blue ocean strategy" (Kim and Mauborgne, 2004). Instead, EVs were designed to replace the ICE vehicles, and thus had to beat ICE vehicles by competing with them on the same performance criteria.

3.3 Dominant design for electric mobility

Then, another question relates to a problem that past EVs have also failed to address: the creation of fit between the product (vehicle), and its components. In order to minimize the costs of industrialization, all the OEMs which tried to develop EV during the 2^{nd} part of the 20^{th} century chose to adapt an existing vehicle and to make a small number of changes to these vehicles in order to minimize their investments. This reasoning had in appearance a strong economic rationale, but in fact this was certainly a mistake, mainly for 2 reasons.

First, minimizing the investments meant that it was impossible to modify the architecture of the vehicle and its component. For example, the OEMs had to put the batteries and the engine at places that were well adapted for an ICE vehicle. So the EV achieved a very low level of integrity with electric energy, although the importance of the "product integrity" (Clark and Fujimoto, 1990) was already acknowledged at the beginning of the 90s.

Second, the case of Toyota Prius has proved since 1997 (its introduction on the market) that a totally new developed car could have an interesting customer value. By making it unique in its range, Toyota has been able to create a vehicle that does not belong to the traditional segments, but had created a completely new segment. All the design of the vehicle has been driven by the concept of vehicle of the 21st century (Morgan and Liker, 2006). Thus buying and driving this car can demonstrate an interest for environment.

3.4 Project scope: from EV product to EV mobility service to convince customers

One of the main reasons why the EV has been thrown out by ICE vehicle is because of the limited usage it can propose to its customer. ICE vehicles propose an autonomy that has always been at least 5 times higher than EV. In the late 19th century EV autonomy was around 50 km, whereas ICE was around 200. Nowadays, the best batteries allow for an autonomy which is no more than 150 km, whereas a typical ICE vehicle can have a least a 700km range, which could in fact be easily extended because of the very high energy-density of diesel or gasoline (10 000 Wh/kg compared to less than 200 Wh/kg for best batteries).

This lack of autonomy is one of the main explanations why global market for EVs has never reached a mass-market size since the beginning of the automotive industry. This problem of autonomy cannot be solved if the scope of the EV is not extended from a single product to a full service of mobility, integrated in a network.

The past attempts to introduce EVs illustrate this need of an extension of EV from product to service. In the past, there have been 2 main types of markets for EVs:

- ✓ fleets managers from large companies, like utilities or postal companies, which manage thousands of vehicles for the use by their employees. For these markets, the question of service is central because the opportunity to switch a fleet from ICE vehicles to EVs is evaluated in terms of operational gain.
- ✓ self-service EVs in urban areas. Much experimentation has been conducted all over the world to test the value of such a service. For example, France has conducted in the 90s several experimentations, of which 2 have arisen great hopes: Liselec experiment at La Rochelle, and Praxitèle experiment at Saint-Quentin en Yvelines (Blosseville, Massot and Mangeas, 2000). Both proved that EV mobility could be attractive, even with limited-range vehicles, provided the customers were sure to find a car well charged, well maintained when they needed it. To sum up, they needed not only a car, but more importantly a service of mobility well designed.

3.5 The unsolved problem of business model

Finally, we insist on the question of business model design. A roll-out of EVs would require to sell a vehicle together with the related services (recharging of the batteries,…). Such a business model, including all the related partnerships needed has never been designed in the past.

In effect, there is a circular problem for introducing EV that no company has solved in the past: no company has ever dared to mass produce EVs, although the only way to benefit from scale economies is to produce at least hundreds of thousands of EVs. As a consequence, it has always been impossible to convince any utility company to invest heavily in the network (thousands of charging points, maintenance network…). And finally, as cars were not mass produced, they remained very expensive, compared to standard ICE vehicles. Then there was not a strong demand for them and finally automotive companies were even less keen to produce large numbers of vehicles. Griset and Laroque (Griset and Larroque, 2006) take the example of France in the early 90s which was at that time the country with the biggest EV ambition: PSA and Renault had, in the early 90s the ambition to sell an annual 100 000 vehicles a year by 2000. The problem they faced was that they never had more than a couple of thousands of orders (partly because the cars were adaptations of existing ICE vehicles), so they did not commit to produce large numbers of vehicles, have never been able to benefit from scale economies and thus make EVs an attractive substitution to ICE vehicles.

This means that a successful introduction of mass-marketed EVs requires that at the same time:

- ✓ at least one OEM committed to design a new vehicle, which will be attractive and well fitted to the electric energy, and also design it to be mass produced, , and thus take a huge financial risk.
- ✓ at least one operator able to invest in the network
- ✓ a third party, which could be a state or public entity, which gives EVs a significant incentive, before scale effects and productivity gains make EV an real competitor for ICE vehicles in terms of end-user total cost of ownership

4 The case of Renault / Better Place

In this paragraph, we focus on the case of a recent multi-companies partnership which aims at mass marketing electric vehicles. More precisely, the OEM, Renault, together with Nissan has set up an innovative business model with a Californian start-up, Project Better Place, started-up by Shai Agassi. Based on the learning from past attempts to introduce EVs (preceding §), this initiative would be the first mass-market success for EV in history, unless an other OEM would be more rapid to roll-out a full EV scheme from now to 2011.

We first describe the partners involved in this strategy. We then highlight the key differences between this case and the past attempts from 19th and 20th centuries.

4.1 Description of the partnership

The partnership between Project Better Place and Renault Nissan (the Alliance) is based on a tasks sharing between an OEM which is developing EVs and a start-up which is about to manage the services needed for the electric mobility.

The Alliance is responsible for the design of an EV, and its mass production. More precisely, Renault will design the vehicle, which will be comparable to ICE vehicles in terms of performances. A joint venture between Nissan and NEC will provide the batteries, which will be Lithium ion batteries, a totally new technology for EV.

Project Better Place will buy the vehicles and the batteries from Renault and Nissan-NEC. It will then sell or lease the vehicles and the related batteries to customers (different types of commercial options for the battery and the vehicle will be proposed to customers). And it is also committed to manage all the services related to the lifecycle of the vehicle: maintenance of course, but more importantly all the recharges of the batteries and also, this is a very specific feature of this initiative, the possible exchanges of batteries that customers will need for their cars.

This partnership between Project Better Place and the Alliance actually is only part of the necessary partnership scheme because other parties are needed to propose EV in a specific country. Obviously, depending on the markets, this partnership will also need a least one electricity provider. And, as the cost of EV cannot be competitive on the short term without any incentive (fiscal, rule,…), a roll-out for EVs is so far envisioned only in countries that agree to adopt a specific fiscal scheme for EV. As of may 2008, two countries have adopted such a scheme: Israël and Denmark. More precisely, Israël is committed to allow a significant tax incentive to EV until 2020. Usually, the cars sold in Israël are heavily taxed. More precisely, new cars are taxed at a level of 79%, hybrids at 30% of their price. But in the case of EVs, the tax level has been set up at only 10% since 2008. This 10% will remain unchanged until 2014, and will rise gradually till 30% by 2019, unless EVs market share reaches 20% (Sandler, 2008). In the case of Denmark, the scheme will be rather similar (Renault, 2008).

In both cases, the first EVs will be sold in 2011, and the partners aim at a real mass market penetration of the vehicle: tens of thousands of EVs in each country. So far, no other mass-market competitor exists, but there is little doubt that many will be attracted by the opportunity, and that Project Better Place and the Alliance will also try to roll-out their scheme to other countries.

Based on the description of the scheme that involves Project Better Place, the Alliance Renault Nissan and a couple of States (Israël, Denmark), we now insist on the specificities of these initiative, based on the knowledge from past EV roll-out attempts described in the preceding § of the article.

4.2 Differences between this initiative and the past attempts

A bundle of elements prove that the design of this whole project is different from all the other past attempts. From the numerous failed attempts to introduce EVs on a large scale, this project has taken into account the main learnings.

4.2.1 The design of the vehicle

First thing, the vehicles that will be proposed to customers won't be prototypes, which is a key feature in the automotive industry to get scale effects. It will be a vehicle designed in accordance to electricity, which means that the customers will benefit from functionalities fitted with an electric mobility. For example, an exchangeability system for the batteries is under study, which requires the car to be designed for allowing a quick operation of drop out and replacement of the battery. This is a very big difference with all the past attempts to introduce EVs: generally, in order to reduce the investments related to the design of a new car, OEMs preferred adapting an existing vehicle with minor changes. For example, in the 90s such companies like PSA or Renault adapted several of their vehicles (Peugeot 106, Citroën Saxo, Renault Clio, Renault Kangoo…) but they only changed the engines (an electric engine instead of an internal combustion engine), and replaced the fuel tanks by batteries, often by reducing the volume of the trunk.

The car designed by Renault is intended to be produced in large volume. This implies that the technical choices for all the components (from the electric engine, to the transmission, air conditioning…) will have, at the same time to be well fitted to the constraints of EV but also to be real design choices, compatible with a mass-production.

4.2.2 The question of autonomy

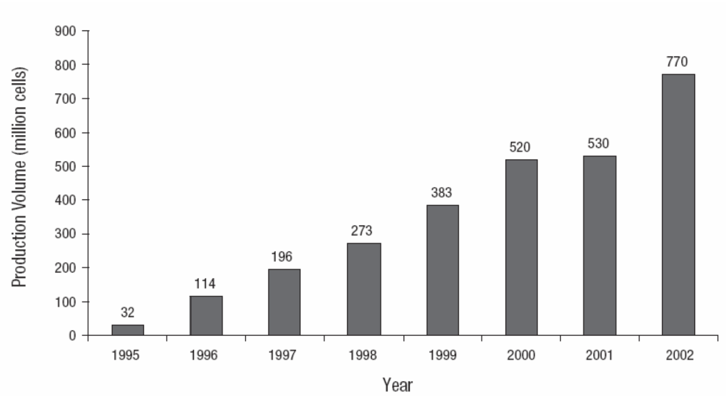
The questions of autonomy and recharge of the battery have been the hardest question to solve for EV since the 19th century. The hard question is about to be solved, thanks to the conjunction of 2 elements:

- ✓ a quick exchangeability of the battery would be offered to customers needing to drive the car for long journeys, solving at the same occasion the tough question of quick recharge for the battery

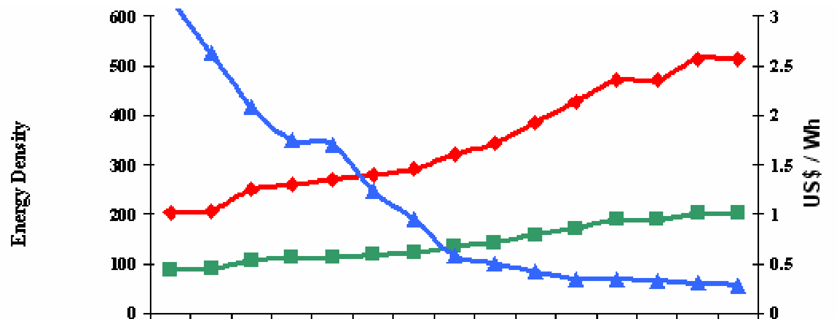
✓ the new generation of Li-ion, that is under development at several battery manufacturers could ensure satisfying functionalities for the customer (an autonomy larger than 100km, even if air-confitionning or other auxiliaries are used)

In the past attempts, many hopes have been deceived because EVs enthousiasts tended to over-estimate the technical maturity of the new energy storage technologies. That was for example the case in the 60s for the fuel-cells technology (Callon, 1980) or in the 70s for the batteries based on Zinc-air technology (Nicolon, 1977),

So, one of the main questions facing potential EV producers is the reliability of the data that suggest the new Li-ion technology is about to provide an efficient battery (100-150Wh/kg storage capacity), reliable, with an attractive price. At first sight, one could think that relying on a new technology for the batteries could be hazardous, and put the EV producers at risk. But, the big difference is that the Li-ion technology is not completely new: it has already been mass-marketed for consumer-electronics batteries, and even if the battery size is 100 to 200 times bigger for automotive application, there is still a huge learning curve that can be used. Thus, we present here data on the Li-ion batteries that have been marketed in for consumer electronics. The graphs below (Brodd, 2006) illustrate the growth pace for Lithium-ion batteries, and the evolution of energy density (Wh/l and Wh/kg) as well as productivity gains over the last 15 years:



Graph 4 – Worldwide Production of Li-ion Cells, 1995 - 2002



	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05
Wh/l	204	208	250	260	271	281	292	321	343	386	428	471	471	514	514
Wh/kg	88	90	108	113	114	119	123	135	143	159	172	189	189	202	202
US$/Wh	3.17	2.63	2.09	1.75	1.71	1.24	0.95	0.59	0.51	0.42	0.35	0.35	0.33	0.31	0.28

Graph 5 – Li-ion Cells performance and cost, 1991 – 2005

These data illustrate that Lithium ion have been mass produced for portable devices for more than 10 years, and that they have made huge progresses both in energy storage capacity and cost productivity. Even if big batteries are much more complex to master than small ones, one can note simply that with data from the end of the 90s, a 20kWh battery could theoretically weight around 200kg, cost around 10000$.

4.2.3 An attempt to design a full service of mobility

It has already been noted that a great difference with the past attempts is that this initiative aims at delivering a car able to be mass-produced at a reasonable price, with functionalities that could satisfy large numbers of users, equipped with efficient Li-ion batteries. The end-users should thus benefit from a stable nominal autonomy provided by the battery, greater than 100km. But more importantly, the roll-out of EVs will be linked to a full service of mobility.

Actually, both in Isarël and Denmark (and possibly in other countries in the future), Project Better Place will set up a full service of mobility for the end-user. It will install a great number of charging stations (approximately 500 000 for a country like Israël). This will be done at the very beginning of the EV roll-out, so that cars will be recharged easily. And also it will offer the possibility to exchange the batteries of the vehicle. In effect, when a driver wants to make a journey longer than the autonomy remaining in its battery, there are only two ways to allow for this with a purely EV. First one is to charge the battery, which is typically an hours long operation (charging an EV battery on a standard socket lasts a couple of hours, and can be reduced to tens of minutes by using special sockets). But there is one other possibility, which is to swap the empty battery with a fully loaded one, provided this operation is not too long. The 1st option has not been selected for a couple of reasons (mainly technical), although the 2nd option appeared realistic, and especially in countries like Israël, where the distances driven are relatively low. To be more precise in the case of Israël, it is a country where there are only a limited number of journeys longer than 150km inside the country. So, by setting up a limited number of exchange stations (less than 200 for the whole country), Project Better Place suggests it allow its customers to make all the drives they want in the country, without any limitation coming from the lower autonomy of the vehicle.

As far as we know, this is the 1st time in EV history that such a large mobility service is designed to assure a massive roll-out of EVs. The only other examples known date back from beginning of 20th century, but this concerned only buses in cities like Paris (so only hundreds of vehicles, operated by professional drivers). This innovative service is revealing an new approach towards EVs for several reasons:

- ✓ it does not rely upon unrealistic assumptions about batteries: it takes the slow level of technical progress in the batteries as a fact, and tries to find out a solution for autonomy with today's technologies
- ✓ this possibility of battery swaps is not a add-on, decided late in the design process: the functionalities offered to the end-user (possibility to charge in multiple places, possibility to swap the battery…) have been imagined early in the design process. So the design is the cars has to take into account these services till their beginning, which is maximizing the chances of success.
- ✓ this is surely one of the 1st times in EV history that the service takes seriously into account the point of view of the end-user: the service is designed to offer to the end-user satisfying functionalities (it does still allow the end-user to make long journeys with the vehicle) at an affordable price. So it is reasonable to assume that this service could be seen in a couple of years as important as have been mobile phones subscriptions for the telecom industry

4.2.4 A attempt to integrate stakes even larger than a mobility service

At this point, we can sum up the main differences between the Renault-Nissan / Project Better Place project and the main preceding attempts to introduce EVs in the past: if it would reach its target, there would be a car on sale designed to be mass-marketed, the batteries would offer a reliable autonomy, and there would be an innovative service to offer to the end-user backed by a full infrastructure of battery charging points and exchange stations. These elements are all related to the car, its end-user, but in fact there is something, which may be very important for all the stake-holders of this project: it has huge external effects, which are environmental, economical and geopolitical.

The environmental impact may be the most obvious. If this project succeeded, it would have the potential to reduce to nearly zero the level of pollution in the city centres. This would have huge external effects. As an example, the Lung Association, which is the oldest voluntary health organization in the United States, recently published a study (American_Lung_Association, 2007), in which it provided data on the health impact (and cost) related to automobile: "The health costs alone generated by the existing motor vehicle fleet (fleet average), in terms of hospitalizations, premature deaths and illnesses, add up to over $7.4 billion per year (2010) including $4.4 billion per year linked to one pollutant, nitrogen oxide (NOx)". In 2006, California GDP reached $1600 billion, so the data presented here is significant: 0,5% of annual GDP is wasted because of pollution related to cars. Further analyses in the study we cite indicate that even with the technical progress of ICE vehicles, pollution effects could be hardly divided by 2, although EVs could reduce them dramatically. In addition to this impact on local pollution, EVs would also have positive effects in terms of CO2 emissions, even if the electricity is not produced by alternative or nuclear technologies: data from EDF (available at edf.transport.fr) indicate that well to wheel emissions of an EV are 50% less important than a traditional ICE vehicle, for the European energy mix.

In addition to the environmental impact, this EV project has a potentially huge economical impact. It could reconfigure the whole value chain in the automotive industry. In effect, a mass-market for EV could:

- ✓ modify the competitive position of traditional OEMs, with some OEMs benefiting from an early roll-out of EVs.
- ✓ transform the network of suppliers: new suppliers are now entering the automotive markets (new battery suppliers,…), while components like engine, air conditioning and others are deeply transformed by the adoption of electricity as energy source

But if this EV project were to succeed, it would not only reconfigure the whole value chain in the automotive industry: it will also modify other economical sectors. As electricity would replace petrol to store the car energy, it would increase dramatically the need for electricity. Obviously, this electricity could be produced thanks to the petrol saved from cars, but this strong demand will also increase dramatically the value of alternative energies, but also nuclear energy. In effect, EVs are very interesting from the point of view of an energy network manager: typically batteries will be charged at nights, when electricity demand is usually low. This would be a great advantage for energies such as wind (winds tend to be more intensive at nights), nuclear (which power generation is steady)… Obviously, such effects would be interesting only if a significant number of EVs would be produced, but one can bear in mind, that a car battery for an 150km range EV should be approximately storing 20 kW-h. So 1 000 000 batteries which would be charged in 12h would require a electricity generator delivery 1 600MW, which is the size of the biggest nuclear plants (eg, 3rd generation reactors EPR), or 240 of the biggest wind powered turbines (eg, Enercon E-126 in Germany).

Finally, this project also has a true geopolitical signification. On of the major side effects of its success would be to open up an alternative to petrol in the automotive market. Today, the automotive market is at the same time the product most dependent upon petrol and one of the major consumers of petrol. The huge power this situation gives to petrol producing countries could then be reduced by a large scale adoption of EVs.

This external effect has been taken into account since the beginning of the initiative by Project Better Place (see for example the internet site of the venture that indicates "freedom from oil dependence" as a major benefit of EV for states, http://www.projectbetterplace.com/project-better-place/benefits).

5 Innovative managerial practices for sustainable development

The case of EV is emblematic of an old technology that, with respect to the past, is "eternally emergent". Back in the 19th century, this technology could have replaced horse, the truly dominant design for individual mobility at that time. But it has been disrupted by the ICE vehicle. Quite surprisingly, EV has survived as a possible alternative to ICE vehicle, unlike all the other technologies that were imagined in the 19th century to offer individual mobility to people (steam power, compressed air,…).

We argue that this very special status of EV in the automotive industry, together with the vanguard nature of the Renault-Nissan / Project Better Place project stimulate new practices for managing innovation.

5.1 An innovative type of partnership between companies

The case presented in this article gives an example of an uncommon type of partnership. For more than a century, automotive industry has been characterized by the existence of a dominant design, which has been several times challenged by potential alternatives. In such a context, one could imagine that EVs, would be promoted only by new ventures. Incumbent companies would not have any interest in promoting EVs, because it requires new engineering capabilities, and also it modifies the value chain, requires to design cars with a new concept of autonomy... The cases of disruptive technologies studied by J.Bower and C.Christensen (Bower and Christensen, 1995) revealed that incumbent companies generally fail to see the potential for the disruptive technologies quickly enough. This does not seem to apply in the case we describe, because Renault and Nissan are true incumbents, and nevertheless they are partnering with an innovative venture, Project Better Place.

Bower and Christensen also suggested that "each company that has tried to manage mainstream and disruptive businesses within a single organization failed". Some companies have experimented new organizations like "innovation domains" (Ben Mahmoud-Jouini, Charue-Duboc and Fourcade, 2007), created by an automotive supplier, that are responsible of creating innovative products which use the knowledge from several technical departments. But the case of Renault-Nissan is thus an intriguing one because these two companies aim at managing this apparently impossible process. The Alliance Renault Nissan aims at being truly ambidextrous in the coming years, because it wants to manage at the same time a growth phase in the dominant design business and also establish a disruptive business. To confirm this view, one can observe that the strategy of Renault managers is to stimulate the growth of their "dominant design" activity (one of the main targets of Renault is to increase the annual output by 800000 vehicles a year between 2005 and 2009) and that at the same time, the company wants to create a mass-market for EVs in the coming years.

Then, it is not completely surprising that the incumbent company may try to explore the disruptive market with a new company as a partner. Actually, two scholars, R.Dyerson and A.Pilkington, who studied the impact of Californian regulations on the introduction on EVs (Pilkington and Dyerson, 2004), suggested that such a disruptive technology could open the automobile industry to new entrants. Their view is partially confirmed by the fact that new ventures have in effect been created: more than 20 new companies are trying to sell electric vehicles or to convert vehicles (information about some of these companies can be found on the internet site of Electric Auto Association www.eaaev.org). They also suggested that these new ventures may try to establish partnerships with incumbent companies, because they may lack all the downstream complementary assets needed to success in the automobile market. In the case of the partnership Renault / Project Better Place, we are facing exactly the opposite situation, because the venture Project Better Place is different from all other EV ventures: it does not try to design and build cars, but rather it focuses on the downstream sales, and services related to the EVs.

What this example already reveals is a new way for incumbent companies to be more agile in evolving markets: the incumbent company does not try here to destroy the ventures proposing alternatives, its does not try to create an isolated spin-off for the innovative activity, but rather it establishes a partnership with a new venture.

5.2 A special role for territories to promote sustainable development

One of the main purposes for the promotion of EVs is evidently that this new type of vehicles can be aimed at sustainable development. As we noted before, there are many reasons supporting this argument: EVs can have a better "well to wheel" CO2 balance than traditional ICE engine (provided the energy is not produced only with coal), EVs also reduce the air pollution in congested city centres, as well as the noise pollution. Thus, adoption of EVs is a typical case of innovation that could provide advantages to people both at a very individual scale (driving in a silent car, which fuel can cost and pollute less), at the scale of a city (local pollution) and also at the scale of earth (it could help reduce global warming). But, because of the different scales of all these advantages, the challenge lies in the following question: should there be a regulator encouraging the introduction of EVs? If yes, at which scale should it be? Which kind of incentive or regulation would produce the desired effect?

The case we present in this article suggests some answers to this question. First of all, it shows that the notion of territory can be a key factor for a successful introduction of EVs. Israel or Denmark are both territories which have been able to propose to automotive manufacturers and service providers well-fitted schemes which allow them to reduce the risk of investing in EVs, and open them credible markets. These schemes are made in both cases of long term fiscal advantage for EVs, which is actually the only way to assure competitiveness to EVs during more than 10 years (approximate time needed for a significant mass-market roll-out). After this time period, the fiscal stimulus may not be necessary any more, because the learning effects and economies of scale could be enough to make EVs competitive in front of ICE vehicles. But these territories have also offered their favourable geography, and social organization. Both Israel and Denmark are small states, in which people buy cars to make commuting on rather short distances. Thus, these territories are not only fiscally attractive for electric cars, but they mobility needs are also well fitted to what EVs can offer today. Thus, we can now sum up what could be a territory able to stimulate the adoption of EVs:

- ✓ It should have the legal power to offer a competitive advantage to EVs in comparison with traditional ICE powered vehicles, and to give assurance that this advantage will last during a reasonable time period (10 years in the cause of automobile)
- ✓ It should have a "rational market" for EVs, consisting for example of people who would like to use a car every day, for relatively short trips (less than 100 kms per day). This market should be at least of tens of thousands cars a year, to justify the assumption of a mass-market opportunity.

In fact, we can draw a parallel between this territories and the technology adoption lifecycle described by Geoffrey Moore (Moore, 1991). In effect, G.Moore is insisting on the importance of crossing the chasm between the market of "early adopters" and "early majority". Obviously, EV has been in this chasm for a couple of decades. But the territories we describe here are maybe the good enabler that could help EVs to cross the chasm.

Still, there remains one intriguing point: we stress here the key role that little and homogeneous territories can play to promote the adoption of a technology for sustainable development, but we do not discuss their motivations. Obviously, there is a huge cost associated with these schemes, and one could wonder whether, at the end this cost would not be supported entirely by Denmark and Israel, and more precisely by their taxpayers. It is obvious that the people of these countries will benefit from the local positive effects of EVs, which are essentially clean city centres in case of success. But at the same time, these two countries offer to OEMs and service providers an opportunity to get scale effects.

So, there is an external effect: in case of success, EVs could be rolled-out in many other countries, surely with much less subsidies (oviously the scale effects will have reduced the production costs of EVs). This means that other countries will benefit indirectly from the subsidies that Denmark and Israel first gave to EVs. In fact, this is not so obvious: in effect, each territory (Denmark, Israel) can also take advantage of the fact they are enablers. As they are the first countries promoting EVs, they can expect some of the new value chain created by this disruptive innovation:

- ✓ in Israël, the government is promoting cooperation between Renault Nissan Alliance and Israeli companies and labs (for example, Israelnationalnews.com reported on March 9th that "The Office of the Chief Scientist, a division of the Ministry, last week opened a public tender aimed at encouraging Israeli companies to contribute to the development of the electric car, to be produced here by Renault. Worthy ideas could get up to 50 percent of their budgets funded by the Ministry, the tender said. In addition, Renault will supply technical and financial help to companies approved to work on the electrical car project. Among the areas that need to be technically polished are the air conditioning system, battery recharging methods and quick battery changes and replacements."). Moreover, one of the major Israeli companies (Israel Corp) invested in Project Better Place. These two examples there will be some sort of pay-back to the tax scheme.
- ✓ in Denmark, the local utility (Dong energy) will be associated to Project Better Place, which will help this Danish company to take some lead in this market. Moreover, the battery cars will help Denmark to solve the problem of unsteady wind power generation because the batteries will be charged at nights. Then, the country as a whole will get some positive effects, which will add to environmental positive effects.

Thus, through this example of EV, we can conclude that territories can implement innovative strategies to promote sustainable development and at the same time stimulate their economy. Providing a good market for an innovation is one of the capability of small and homogeneous territories, which are able to make decisions quickly and to embark for long term schemes.

5.3 The strategic management of product renewal

Finally, we argue here that the case of EV reveals and differentiate the different innovation strategies that a car manufacturer could implement in front of the sustainable development challenge. Actually, for a couple of years all the OEMs have faced the obligation to reduce the emissions (CO_2, NO_x, particles…) of the cars they produce.

So when one OEM has different choices to establish a strategy for innovation, it has to allocate its resources among different kinds of strategies:

- ✓ it can decide to stay in the dominant design of the automotive industry or try to go outside. The dominant design here is the ICE vehicle. Hybrid forms of the ICE, which electric drive cannot exceed a couple of kilometres and which batteries cannot be recharged with an electric slot obviously remain in the dominant design.
- ✓ it can decide to focus its innovation strategy on a technological roadmap, relying on a strategy pushed by the research department, or on a short term and opportunistic strategy guided by the opportunities pulled by program managers

We can sump these different strategies in the following table:

Innovation Strategy	Program pulled	Research pushed
Staying within the dominant design	A	B
Going outside the dominant design	C	D

The rationale for strategies A, B and D is quite easy to understand, and it as already applied by many companies. Let's explain why:

- ✓ in the strategy A, the company invests in innovation if it can be applied quickly and successfully to the market, without changing the dominant design of the car. In such a strategy, the OEM does not make a lot of research in-house. It is an opportunistic strategy for the OEM which can then rely on incremental innovations brought-in by suppliers, and decide to apply them when it detects a market for them.
- ✓ in the strategy B, the company invests in innovation strategy through funding of the research. And it focuses its research on innovative features that can easily be applied to the vehicles because they stay in the dominant design. The strategy of the company is then to anticipate the learning effort, and to explore the different alternatives of a future innovation, which has no market at the time research is done, but which would technically fit to the existing products.
- ✓ in the strategy D, the company chooses to invest some of its research budget outside the dominant design. This is the traditional way to maintain a level of knowledge and competence on potentially disruptive technologies.
- ✓ the strategy C seems the hardest to manage. In effect, programs which are clusters of projects, generally use the knowledge accumulated by engineering departments. In this case, the strategy is to adopt a program structure to manage the learning process outside the dominant design. Recent case studies in the automotive industry revealed some difficulties of such processes (Aggeri and Segrestin, 2007)

The learning from the Renault case is, so far, that type C strategy can have a high lever effect. In this case, the company is working on narrow but clearly identified targets: a first market in Israël, an other in Denmark, and maybe others to come. This strategy may not allow to explore and prototype all the technological opportunities, but its focus on real-market needs reduces the risks of commercial failure and reinforces the quality of the selection process. This example reveals a new role for program managers in the company: although the project management revolution (Midler, 1993) established a great role for heavyweight project managers (Fujimoto and Clark, 1991), these managers normally used the engineering departments as a resource to design attractive cars more efficiently, more rapidly. Here the program manager is causing renewal and organizational changes in the engineering departments. This EV program is thus experiencing a new stage of the project and program management in the companies: programs are not only renewing the products of the company but also its organization of engineering and innovation management. The traditional partition between Research and Development phases is thus being replaced by a management which integrates the whole life-cycle of an innovation.

6 Conclusion

For more than a century, Electric Vehicles have always fascinated men, even if they failed many times the market test. Today, the context for EVs is favourable for an obvious bundle of reasons: considerations about pollution, energy supply…In front of this new context, EV is once more characterized by a wave of enthusiasm. Many companies are trying to promote this innovation, disruptive for the automobile industry. By referring to the past and failed attempts to mass-market EVs, we have shown that a great knowledge has now been built on the success conditions for an EV roll-out.

Compared to these attempts, the new initiative by the Alliance Renault-Nissan and Project Better Place seems to fulfil many of the conditions for success we have identified. The success of this initiative is still uncertain, and there are certainly many surprises on its path. That is why an action-research was launched at the end of 2007 in cooperation with Renault.

Even if it began a short time ago, this initiative has revealed some interesting findings, which can enrich our knowledge about innovative strategies aimed at sustainable development. We have shown that new patterns of cooperation, especially between incumbents and new ventures can emerge, which modify the traditional view of competition in new markets. We have highlighted the special role that territories can play to make possible or speed-up the roll-out of a new kind of products, and initiated a larger reflection on the competitive advantages that can be levered by different territories. Finally, we have suggested that the case of EV at Renault could open the road to a new way to manage innovation in large companies.

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