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Entry Strategies in the Fast Growing Electric Vehicle Market

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Introduction

Recent developments in regulatory emission standards in the hope of restraining the threat of global warming, turbulence in oil prices, technology innovation and especially, enhanced consumer and government interest in the green economy have brought to a reviving interest in alternative powertrain[1] technologies. More precisely, after a long dormant period, current environmental concerns coupled with the search for sustainability, and most importantly the rise of new players which have boldly heavily invested in the booming "0" emission automotive sub-industry, have awakened incumbents, most of which showed a lagging situation in the electrified powertrain technology knowledge and commercialization. In front of the contingence of being disrupted by new entrants or established competitors in an evolving market with strong growth potential, incumbents are being faced with a set of contrasting strategic decisions, which will determine their competitive future path.

In this context, automakers with a constrained budget have to make decisions on which technology to invest on, which to develop commercially, when to go to market and in which manner. Collaboration strategies must also be taken into consideration when analyzing entry strategies as they entail the risk of losing precious proprietary technologies and knowledge on one side, but reduce the research and development time and costs in an uncertain environment on the other side.

Hence strategic decisions will have strong implications for the future evolution of the industry and its players given technology's strong path dependence caused by the self-reinforcing mechanisms which are characteristic of innovations distinguished by network externalities.

This thesis then, studies the main drivers of technological innovation for automotive powertrains, and more precisely the strategic decisions concerning investments, timing, mode and scope of entry and collaborations in the EV market. The aim of the

[1] The main components that generate power and transmit it to the road surface.

thesis is to add to the knowledge of strategic management of technological innovations in the field of electrified powertrains, mostly focusing on Electric Vehicles[2]. Moreover, as time and commitment seem to be the greatest discriminants in innovation management and relating strategies, an in depth analysis of the greatest[3] established automakers' entry strategies has been made. In particular, through the study of publicly available data, corporate master plans and specialized reports; time of entry, segments covered, models per segment and amounts invested have been analyzed to determine what will the main investment trends be for the period 2017-2021, year in which the EU emission regulations enter into force.

By defining investment strategies based on both a dynamic and situational analysis, recommendations have then been made for automakers with a given current situation, wishing to gain a precise competitive position in the next few years.

Following the discriminant of time, short, medium and long term projections have then been made regarding the industry's evolution to explain the possible behavior adopted by certain industry players which seem not to be following the trend of powertrain electrification.

To complete the analysis, the situation and strategies of new players, the influence of other innovative technologies over EV adoption and the conditions under which the diffusion of alternative powertrains will really benefit society have also been briefly studied.

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[2] With greater attention reserved to battery powered electric vehicles over fuel cell electric vehicles.

[3] By volume and market capitalization.

1. Management of Technological Innovations

1.1 The importance of innovations

"Innovation[4] is, in its purest essence, knowledge—knowledge to solve our problems and pursue our goals" (Simon 1973)

According to Barczak et al. (2009) on average one-third of firms' profits in a wide range of industries derive from products developed in the last five years[5]. In this respect, technological innovations[6], which enable firms to protect their margins against local and global competition, have become the most important drivers of competitive success (Schilling 2013).

In a world where the big global players have the funds to continuously launch to market new products, firms that do not pursue an innovation strategy find themselves quickly cut out and obsolete, with little margin for competition. In this environment, non-innovative firms can heavily suffer from competence-destroying innovations[7] and run out of business in a short time. This is particularly true for industrial firms, which are particularly technology-intensive, and whose competitive advantage greatly depends on their products and processes. Being the first to patent a significant technology can shift market power away from incumbents towards new players, if the right market conditions exist.

1.2 The importance of having a clear strategy in product innovation

According to Stevens et al. (1997) it takes about 3000 raw ideas to produce one new successful product, moreover according to Castellion et al. (2013), new products

[4] The practical implementation of an idea into a new device or process (Schilling 2013).

[5] "We sold a vehicle every 30 seconds in March, continuing our record-breaking start to 2017. […] New products are driving this success […] We are no longer an attractive alternative but a serious rival to our established competitors. With new models on their way throughout 2017 this momentum looks set to continue." Jaguar-Land Rover UK Managing Director, Jeremy Hicks.

[6] Defined as the act of introducing a new device, method, or material for application to commercial or practical objectives.

[7] Tushman et al. 1986.

actually making it to market fail at a rate of 35-40% on average. Firms making innovative strategic decisions will thus have to decide which innovations to invest on, when to invest and how to access them. These decisions are particularly hard to make due to the uncertain environment which characterizes this decision process and the high risk for investment losses. Future demand, technological progress, substitution effects, industry dynamics etc. are all factors which are difficult to forecast and for which there is no prediction guarantee. When put into perspective, seeing that if the average research spending per new big drug in the pharmaceutical industry is around \$4 billion, with peaks of \$11 billion (Forbes 2012), it becomes necessary to think that an innovation strategy must be put in place in order to maximize the success rate and minimize costs. This will be true both for new disruptive firms in order to gain market leadership and for established firms[8] in order not to be overthrown by new entrants.

1.3 The sources of innovation

When pursuing an innovation strategy, firms must consider which will the main sources of creative ideas and practical solutions be. Innovations can be developed in-house by a firm's employees, or externally. The latter case involves the creation of linkages between the firm and its external environment such as Universities, individuals[9], R&D firms and entities, customers, suppliers, competitors and complementors. These relationships allow the flow of ideas or of new development opportunities from the external environment to the firm's R&D department. Moreover, relationships between the firm and its external environment can vary from informal contacts up to strategic alliances or joint ventures, when the decision of investing in a given technology has already been made.

This external dependence is mainly due to the fact that even though internal R&D departments are crucial to create innovative products and gain a competitive advantage over rivals, this process can be inefficient and highly costly, especially when

[8] Which are usually characterized by a certain degree of inertia (Teece et al. 1997).
[9] Users or inventors

particular features of the innovation depend on enabling technologies[10] which do not belong to the firm's core competencies. In fact, as seen in Roberts (2016), there is a strong tendency in companies worldwide to "shift towards acquiring more key technologies from outside" relying on Universities, joint ventures and alliances, with an average 40% maintaining high frequency collaborations with outside organizations. In this context the concept of absorptive capacity[11] has become central, as what really matters in a firms' ability to innovate is its capability to recognize and assimilate new external information and convert it in commercially viable innovations, be it products or processes. In Cohen et al. (1990) we see how this capacity is mainly a "function of the firm's level of prior related knowledge" underlying how external and internal sources[12] of knowledge are complements and both fundamental elements of a sound innovation strategy. This is particularly important during the formation of collaborative relationships such as informal networks and more importantly strategic alliances as the firms which possess the highest absorptive capacities are the ones which benefit the most from the interaction. The Toyota 1983 example shows how thanks to a strong absorptive capacity, companies are capable not only of learning from competitors quickly, but also to surpass them and gain a competitive advantage if the latter are bureaucratic, inward-looking companies.

1.4 The main types of innovation

By definition all innovations contain an element of novelty in them, however they do differ under certain aspects.

In Schilling (2013), innovations are classified according to 4 dimensions:

1. product or process, where the first refers to the creation of new or differentiated output by an organization, while the latter refers to new more efficient or effective ways an organization can conduct its business and produce value. The two are highly interdependent and often tend to occur simultaneously.

[10] Component technologies that are necessary for the performance or desirability of a given innovation
[11] The ability of an organization to recognize, assimilate, and utilize new knowledge
[12] internal R&D contributes to a firm's absorptive capacity (Cohen 1990).

2. radical or incremental, where the difference can be found in the degree of newness and differentness with respect to existing practices. Obviously, the degree of radicalness of an innovation is directly linked to the degree of risk during the investment phase, since there is higher uncertainty regarding the technology and its commerciality with respect to incremental innovations. Moreover, the potential to overthrow incumbents is higher when the degree of innovativeness and non-imitability are high.

3. Competence-enhancing or competence-destroying, depending on whether the technology builds on the firm's existing capabilities or makes them obsolete[13], requiring a new set of competencies and skills.[14]

4. Component or architectural, where the first implies changes to single components or modules of an existing technology[15] while the latter implies a reconfiguration of the elements within a technology bringing to a major change in design[16]. Firm's ability in initiating one form of innovation or the other highly depends on the level of knowledge the firm has regarding the single components and the system as a whole.

The dimensions are interdependent and sometimes overlap with an innovation falling inside more definitions, whilst sometimes only partially manage to capture the complexities behind the innovative phenomenon. However, it is important to notice how each and every type of innovation, from the least to the most radical, do not guarantee a commercial success if firms fail at pursuing a correct innovation strategy. A clear example would be obtaining a new technology after heavy investments for which there is actually no market, or whose performance depends on that of an undeveloped enabling technology. In both cases the value of the technology at present would be low, and the chance of making a loss on the investment enhanced.

[13] Such as steam vs. diesel locomotives (Chandy 2009)
[14] Tushman et al. (1986).
[15] Tellis et al. (2008)
[16] Tellis et al. (2008), Henderson et al. (1990)

1.5 Technology improvements

Performance improvements in many technologies follow an S-curve evolution with respect to the amount invested per unit of time. If performance improvements are slow during the initial period because of poor understanding of the technology, limited attention by the scientific community, limited knowledge of their reliability and commerciality, and limited funds in the initial stages, as soon as the technology establishes a certain degree of legitimacy and understanding, improvement begins to accelerate. The acceleration is mainly due to an increased base of scientist and developers studying the legitimated technology, and thanks to increased budget spending[17]. As the technology reaches maturity, every marginal improvement in performance will imply higher and higher investment costs as the improvement margin will tend to 0 and the technology reaches its limit. During the maturity phase technologies are often substituted by discontinuous technologies[18], which demonstrate a better performance for the same market need.

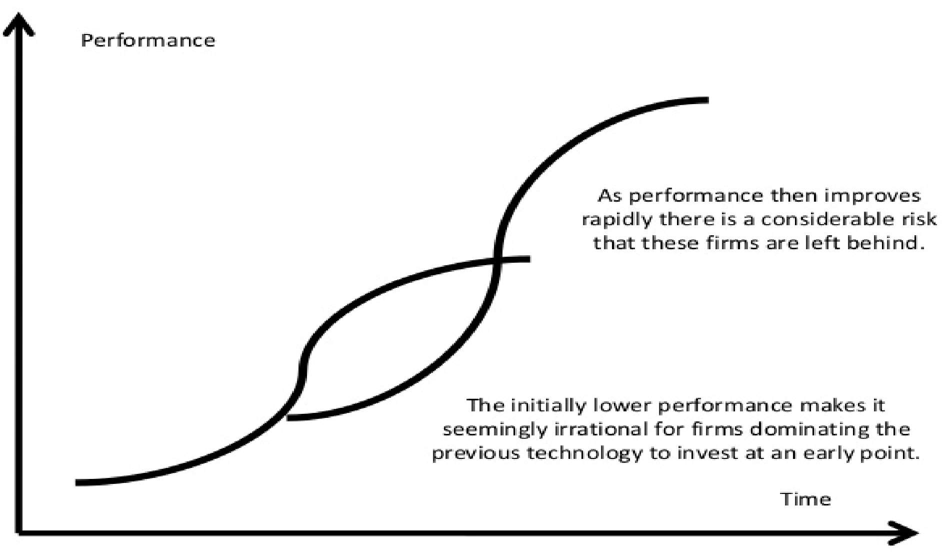


Figure 1, Technology S-curves.

Discontinuous technologies are particularly interesting for the fact that they are usually brought forth by new entrants and pose incumbent firms in the difficult position of deciding whether to continue maximizing the performance of the profitable

[17] When improvement potential is high, high budget spending when there is low space for improvement will only bring minor improvements.
[18] A technology that fulfills a similar market need by building on an entirely new knowledge base.

incumbent technology, or heavily invest on the new disruptive technology with the risk of cannibalizing current profits and reducing the incumbents' margins. It is important to notice that if the performance gap between the two technologies is wide, the new technology is very likely to displace the incumbent, however the time it will take to do so can vary significantly depending on the industry dynamics and the incumbents' reactions. If in fact, it was thought that disruptive innovations had the potential and risk of making incumbents vulnerable to attacks of new entrants, a study by Bergek et al. (2013), shows how in many industries, incumbents have "the capacity to perceive the potential of new technologies and integrate them with existing capabilities", greatly reducing the risk of being disrupted.

1.6 Innovation diffusion curves and market forecasts

Technology diffusion curves plot the spread of a technology through a population by graphing the cumulative number of adopters over time. The S curve is mainly due to the fact that the population is initially unfamiliar and unconscious about the technology and adoption is low. Also, at the beginning, as seen in the technology S-curves, the innovation might also be immature or not as performing as current technologies. However, as knowledge spreads due to internal and external communication channels and the innovation improves, diffusion speeds up as the product is adopted by the mass market and finally slows down as the market is saturated. So, as explained, the diffusion function is also partly dependent on the performance improvement S-curve since user adoption is proportional to the technology's improvement and reliability. Furthermore, as knowledge of the innovation and its enabling technologies improves, production costs diminish and competitors enter the market lowering the final purchase price and increasing user adoption[19]. New generations of a technology, or new discontinuous technologies usually arise during the maturity phase of the incumbent innovation thanks to increased understanding of the underlying and enabling technologies introducing a substitute on the market. However, even if a new technology may offer greater

[19] Pricing strategy during growth phase as seen in Salvendy (2001)

performance and a greater potential market respect to the existing one, firms may delay investments due to the lack of sufficient complementary resources and customer education which would imply a low rate of adoption and low ROI in the first period with the risk of bankruptcy. Moreover, incumbents may want to "milk the cash cow" as long as possible[20], before turning to the new technology. For many reasons, not always are markets ready for new technologies, time of entry becomes crucial in these situations. Apart from that, the cyclical nature of innovations implies that at a point in time, the superior technology will replace the incumbent one. When the technological innovation overturns the existing competitive structure[21], we witness the process of creative destruction which gives rise to a new industrial structure led by new players.

1.6.1 Roger's Diffusion model

"Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003).

According to the theory, the pace and reach of innovation diffusion is mainly determined by 4 elements: quality of the innovation, communication channels, time and the social system.

In Roger's model, which is one of the most cited publications in diffusion research[22], the main diffusion mechanism is that of communication channels[23], which have the capacity to spread the idea through a domino effect. These can be divided in mass media, mainly based on information technologies, which have the capacity to reach the mass, and interpersonal communications, mainly WoM[24], which has a stronger influencing power. Since Rogers' theory was greatly influenced by fields such as anthropology and sociology, social aspects play a central role in the model, with

[20] If the current technology allows for good margins
[21] The process of industrial mutation destroys the existing economic structure, incessantly creating a new one (Schumpeter 1942).
[22] Together with that of F. Bass
[23] The mean through which information is shared among individuals
[24] Word of mouth

factors such as peer influence, or the social system's characteristics[25], greatly influencing the speed of adoption. Due to this fact, we can see how, even though the decision process of the members of a social system hinges upon each individuals' perceived value of the innovation, in the end the real influencing factor for the majority of the population is the decision made by the system's other members[26]. This can be found in the diffusion curve, which grows steeply after a certain percentage of the population adopts the technology.[27]

Central to the decision process is also the innovation quality. In fact, when faced with the choice of whether to adopt a new technology or not, potential adopters evaluate an innovation based on the following elements:

1. Relative advantage, which measures the degree to which an innovation is perceived as being better than the technology it replaces. The greater the perceived gap, the easier the adoption.

2. Compatibility, the extent to which the innovation is compatible with the existing system, norms and values.

3. Complexity, the degree to which an innovation is perceived to be difficult to understand or use.

4. Trialability, the testability of an invention before making the purchase decision. Free and diffused trials enhance users' product testing and increase the probability of adoption.

5. Observability, the degree to which the positive outcomes accruing from the use of the innovation are visible to others. Observed effects foster WoM and trial from potential adopters.

It is important to notice how potential users judge the product as a whole, hence the higher is the total perceived benefit to the final users, the higher is the probability of initial adoption and speed of diffusion.

[25] Homophily and heterophily affect how individuals in a system interact
[26] The bandwagon effect
[27] 16% corresponding to the start of the early majority phase

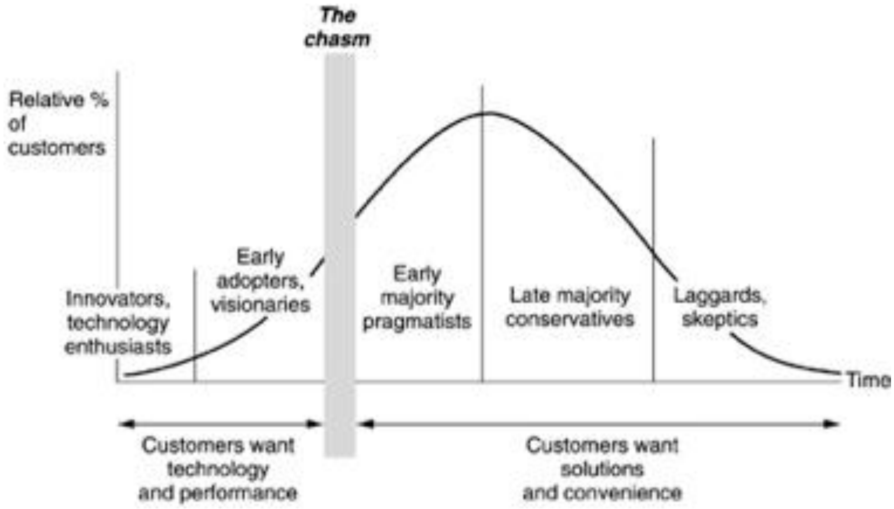


Figure 2, source: Moore (1991).

Another explanatory variable is time, since the “adopter categories”[28] seen in Figure 2 can be classified as a function of time, where the degree of the adopter’s innovativeness can be seen as a function of his time of adoption with respect to that of the social system, with each category acting as an influencer over the next group. Time is also related to the level of uncertainty and risk associated with a technology, where less innovative adopter categories postpone adoption based on their level of risk-averseness. To decrease uncertainty individuals should be informed about the advantages and disadvantages of adopting the innovation to make them aware of all of its consequences. As time passes, more information becomes available to the social system, spurring adoption of the more risk-averse.

This creates the bell shaped distribution curve, which once divided by time, presents the adopter categories for product share, characterized by their degree of innovativeness. Hence, Roger’s model represents a step by step diffusion process, whereby each category through the use of internal and external channels communicates with the next, triggering the domino effect which will ultimately bring

[28] Innovators, early adopters, early majority, late majority, laggards, with adoption rates of 2,5%, 13,5%, 34%, 34%, 16% (Rogers, 2003).

to the total adoption[29], with the adoption by laggards[30] indicating the reached maturity of the technology.

Crucial to the successful diffusion of a technology is its rate of adoption[31], which highly depends on its perceived attributes, the influence of communication channels, the characteristics of the social system[32] and the presence of change agents, such as opinion leaders and organizations.

Out of all the attributes, however, the strongest diffusion predictor is assumed to be that of Relative Advantage. If this were the case, direct or indirect financial incentives could have a big effect on the rate of adoption by increasing the perceived relative advantage[33] of a technology to the social system.

This said, innovations do not always reach their full market potential. In these cases we talk about failed diffusion, where the technology does not reach 100% of adoption due to deficiencies in any of the influencing factors stated before, such as miscommunication regarding the benefits of the innovation, or social stigma over the use of the technology.[34]

An important contribution to the theory was brought by Moore (2014), who argues there is a chasm between the early adopters and early majority categories, where the first are described as visionaries and the latter as pragmatists, hence being driven by strongly contrasting ideals[35].

Firms must be able to push the innovation across the chasm with the use of marketing in order to continue the diffusion process. Moore's contribution is particularly applicable in the case of discontinuous technologies which require a strong change in the adopters' behavior, leading to failed diffusion where this does not arise.

[29] Where the conditions make it possible, not all innovations are a success.
[30] Which represent isolates in the social system, or very traditionalist individuals, who are suspicious towards innovations.
[31] "the relative speed with which an innovation is adopted by members of a social system" (Rogers, 2003).
[32] Norms or network interconnectedness, degree of homophily vs. heterophily.
[33] By decreasing its cost.
[34] Los Molinos experiment resulting in failed water-boiling campaign (Rogers, 1962).
[35] At the chasm a sort of reverse bandwagon effect is in place.

1.6.2 The Technology Evolution model

Utterbach et al.(1975) proposed a technology life cycle model according to which a technology passes through various distinct phases before reaching a dominant design[36].

During the first stage, uncertainty and lack of knowledge over the technology and its potential market are high, the technology might be unreliable, expensive or complex to use. In this unstable environment, producers tend to experiment with product features trying to assess which the market values the most. As the market grows from niche adopters to the early majority, the innovation starts taking its final form until a dominant design emerges.

Once the dominant design is set, firms adopting the technology can focus their investments on improving processes or making incremental changes to the innovation. In this phase, product differentiation and production improvements due to process efficiencies lead to the adoption by the mass market. It is during this phase that firms usually recover their investments and profit thanks to mass adoption. This is also the phase during which incumbent firms tend to lose flexibility by concentrating investments in finding incremental innovations in the profitable dominant technology.

But as the firm's current business structure specializes at competing around the current dominant design, the rigidity will eventually become a barrier to new innovation. The rise of a new disruptive dominant design will then mean the end of the old technology.

1.6.3 The Diffusion of Innovations model

"Long-range forecasting of new product sales is a guessing game, at best. Some things, however, may be easier to guess than others" (Bass, 1969).

[36] A product design that is adopted by the majority of producers.

The model represents the rationale behind the interaction among current and potential adopters of an innovation and consists of four key elements: innovation, communication channels, time and the social system. It was developed to predict the timing of initial purchase of new consumer products under the main assumption that the latter is linearly related to the number of previous buyers through a WoM "contagion process".

As seen in Rogers' stages of adoption in par. 1.6.1, individuals who adopt the product at different points in time can be aggregated in 5 groups. The innovators, whose timing of adoption of the new product and decision process are independent from the decisions of the other individuals[37] in the social system, and all the others[38], which Bass groups and defines as imitators, whose timing of adoption is dependent on the pressure arising from previous adopters, with the pressure increasing for later adopters.

According to Bass, mass media and WoM are the main communication channels by means of which innovations are diffused, each having a different influencing potential on individuals based on their distinctive personalities.

The main application assumptions are that the model can forecast the long-term sales pattern of new technologies and durable products by either: using sales data of a few initial time periods or alternatively in absence of actual data, applying variables found from the sale of previous similar products or technologies whose development pattern is known. Resulting will be a prediction of the potential market, and sales per period. If these forecasts were found to be reliable they would be of great use in an innovation strategy to decide the right timing and mode of entry.

[37] In Rogers' model, innovators interact with each other.
[38] Early adopters, early majority, late majority, laggards.

1.7 Limits of Technology S-Curves

According to Christensen (1992), even though diffusion models do provide useful insights at an aggregate level, the application of the model for managerial planning seems ambiguous.

This is due to different considerations. First, the use of the model in forecasting may give rise to a self-fulfilling prophecy. This could be the case, when innovation improvements decrease not due to actual potential of the technology, but because of a decrease in investments caused by a beginning low estimated potential margin. Second, the complexities surrounding the world of innovations are so vast that improvements in enabling technologies may give new life to a once considered mature innovation. This effect can hardly be predicted in advance when taking a managerial decision based on an S-curve. Third, evidence from Foster (1986), shows how there is no clear evidence regarding first mover advantages and that in many cases later entrants managed to match the performance gap with first-movers. However, always Christensen (1992b) points out how the opposite is true, and in particular that first-mover advantages are extremely important at points of architectural technology change.

Moreover, Meyers et al. (1999) argue that the development of diffusion theory has been highly fragmented, resulting in the production of multiple models which only apply to particular situations. Another aspect of criticism is that the model assumes an oversimplification of complex human interactions, which are difficult to quantify and measure (Damanpour 1996). This means that by oversimplifying, diffusion models might miss critical adoption predictors resulting in unreliable forecasts.

1.8 The importance of dominant designs

As stated earlier, as innovations move through their technological cycle, they inevitably end up adapting to a dominant design responding to the mass market needs. As producers stabilize around this design, their efforts tend to be concentrated on improving production efficiency, marketing and market share of this dominant design, losing sight of alternative designs which might have satisfied the same need. In this situation, we can see how innovations are extremely path-dependent[39].

The rise of a single dominant design[40] can be due to different factors (Schilling 2013):

1. usually, innovations are subject to increasing returns to adoption, where the technology becomes so more valuable as the number of adopters increases. This is particularly true for platform technologies, where the benefits of use are proportionately linked to the number of users. Network externalities[41] are also central when the added value of complementary goods is a main decisional factor.[42] Makinen et al. (2011) show how complex technologies exhibit increasing returns to adoption at first as adoption increases faster than technological improvements, but slows down as the technological complexity increases and experience accumulation becomes more resource consuming.

2. as revenues for a given technology increase, reinvestment in the development of incremental improvements further consolidates the design's market share. This investment effort creates a self-reinforcing mechanism, which further improves the dominant design vis-à-vis alternative solutions.

3. most importantly, as product diffusion spreads, complementary asset producers are incentivized to concentrate their production efforts upon the most adopted technology creating specialized products customized for that innovation. This is one of the most important factors, since the presence of complementary assets supports the self-reinforcing mechanism by greatly increasing the relative advantage of the dominant design, regardless of its relative performance.[43] This is one of the most important effects of path dependency, as once a certain

[39] Decisions we are faced with depend on past knowledge trajectory and decisions made, and are thus limited by the current competence base (FT), a classical example being the QWERTY keyboard.

[40] A single product or process architecture that dominates a product category (>50% market share) becoming a "de facto standard" (Schilling, 2013).

[41] When the value of a good increases with the number of users (installed base) of the same or a similar good.

[42] It can be noticed how the value of a console, its installed base and the presence of complementary goods are all interdependent and lead to a self-reinforcing cycle.

[43] Meyer et al. (2008) show how hydrogen vehicles face a strong entry barrier for what regards the missing complementary fueling infrastructure system.

commitment by complementary producers is reached, it becomes difficult for alternative designs to compete in the market.[44] Government intervention could have a great impact in this context.

4. as production of a technology increases, firms become more efficient lowering production costs per unit produced and increasing unit margins. Positively related to the cumulative output are also product and process knowledge. These learning effects translate in an increased product performance and lower production cost, increasing the relative advantage gap with respect to competitive designs. The learning curve effect is particularly important as it creates a first-mover advantage on specific technology designs. Furthermore, as firms increase their related knowledge and as production volumes increase, they also increase their absorptive capacity[45] to assimilate external knowledge and improvements (Cohen et al. 1990). Due to this learning effect it becomes more difficult for late-entrants to compete in the dominant design market.

As shown then, the rise of a dominant design creates a self-reinforcing mechanism which will ultimately create a de-facto standard and bring to the elimination of alternative competing technologies.

In this context, if the first-mover manages to create sufficient entry barriers the competitive structure will evolve towards a Monopoly. If as explained, the insurgence of a dominant design may create this oligopolistic structure, a consequence may become the creation of coalitions in such a way to influence the selection of a preferred technology (Wade 1995). This results in a strong influence of path dependency on innovation and consequently to the importance of having a clear innovation strategy in place. Choosing the right time of entry, creating the right collaborations, adopting the right marketing strategy, finding new product uses to increase installed base or extending the installed base indirectly by increasing

[44] Nia et al. (2016) show how platform and complementary value are interdependent, while different platforms are competitors rather than complements.
[45] Which has also effect at the industry level via spill-over effects.

compatibility with other products[46] (Thun et al.), [47] will make the difference between controlling the dominant design[48] or being left behind. Important could be the contribution of public policy in determining the technological path through the use of incentives (Fagerberg et al. 2008).

1.9 The Importance of Network Externalities on technology value

The value of technologies characterized by network externalities[49] can be calculated as the sum of the stand-alone value[50], the installed-base value and the complementary goods availability value.

When comparing products then, adopters tend to compare not the individual technologies, but the perceived value of the whole system. This creates the possibility for producers to push the product by advertising the presence of complements, a larger user base, or a wide compatibility with existing technologies, playing with this perceived value effect.

When the product or its complements are still not available, firms can postpone buyers' decision moment, gaining valuable time, by advertising and promoting the forthcoming launch of their claimed "superior performing" product, or of a wide array of complements.[51] A common practice is that of promising an unrealistic[52] product quality in the hope deterring rival entry, gaining the necessary time to market and stimulating future demand (Ofek et al 2013). This strategy is particularly used when a dominant design has no yet been chosen or where network externalities are fundamental for product growth and diffusion. It is also important, when first movers could build entry barriers by gaining a strong brand image or by creating a lock-in

[46] Thun et al. particularly stress the importance of the Bandwagon and Penguin effects in technologies showing network externalities.
[47] And following the right market trend etc.
[48] Sponsorship by a large powerful firm may also create a lock-in effect on a given technology path.
[49] "The effect that one user of a good or service has on the value of that product to other people. When a network effect is present, the value of a product or service is dependent on the number of others using it"
[50] Technological relative performance advantage
[51] This strategy is defined as vaporware
[52] Where anticipated value is disproportionate to actual value

effect.[53] Ofek et al. (2013) also find that incumbent firms tend to use this strategy when their market forecasting capabilities are weak and wish to gain time on the market.

1.10 Timing of entry

Entry timing is a fundamental decision in the design of a firm's innovation strategy. As suggested by Klingebiel et al. (2015) a timing-strategy alignment is related to performance with early entrants featuring a broader, less selective innovation portfolio and late movers featuring a narrower, more selective portfolio. The first portfolio tries to cover high failure rates, while the latter tries to target a specific market need, since the failure risk has diminished. The main difference can be found in the level of market uncertainty and the risk profile of the strategy, with the first aiming at obtaining a temporary monopoly with a higher degree of risk, and the second aiming for more certain cash flows with lower rewards due to competitive preemption.

Moreover, Schilling (2013) stresses how in industries characterized by increasing returns to adoption, timing is fundamental since when applied correctly, it tends to produce that self-reinforcing mechanism which will eventually bring to the creation of an industry standard or the insurgence of a Monopoly. On the other hand, the same characteristics, which make early entrance in these industries a potential success, may render these technologies highly risky, since the future adoption will depend not only on the products' perceived quality, but also on the availability of complementary assets, and the presence of a large user base. The absence of any one of these components could lead to a failed diffusion and the rise of an alternative technology.

At the same time, taking the incumbents' point of view, Mitchell (1989) suggests that early entrance in a new subfield will be more likely when the incumbent's "core products are threatened or when it possesses industry-specialized supporting assets". On the other hand, entry will be postponed in uncertain markets when these do not pose a competitive threat to the current incumbent's business model.

[53] i.e. Videogame console producers, software producers etc.

Quantitatively, a study by Lilien et al. (1990) on timing of entry found that the likelihood of success of third and fourth entrants was higher than that of first, second, fifth and sixth, highlighting how success is stronger when the product is launched in the introduction or growth stage, and when part of the market and product uncertainty has diminished and production and marketing expertise have increased.[54]

First mover advantages can be summarized as the following:

1. Brand loyalty and technological leadership: with the second giving rise to Monopolies where the fundamental technology is protected by a patent, copyright or is difficult to imitate.

2. Preemption of scarce assets: when first entrants secure the supply of strategic scarce resources such as permits, exclusive supply or purchase agreements, or access to key locations.

3. Buyer switching costs: limited compatibility, the complexity of learning how to use a new technology or the need to re-acquire all complementary assets can become a strong entry barrier against would-be competitors.

4. Production scale and increasing return advantages: first entrants may benefit from riding the learning curve and lowering unit costs[55] or increasing product performance before other competitors manage to enter the market.

First mover disadvantages instead could be:

1. First-mover costs: first movers typically bare most of the R&D, development, distribution creation and market awareness costs. Early followers can free-ride on these expenses and invest on bringing a better performing product to market.

[54] Other two studies by David (1985) and Liberman et al. (1998) confirm this hypothesis that in many cases early entrants manage to create a first-mover advantage, also finding that often the first firm to enter is also the first one to fail, causing early followers to outperform first movers. Furthermore, Golder et al. (1993) found that market pioneers have a high failure rate and low market share with respect to early leaders

[55] By increasing product margins, firms create a valuable price cushion thanks to which a potential price war could become a credible threat.

By having to sustain all these expenses, with high uncertainty of future revenue streams, first mover strategies can be unbearably risky for most firms.

2. Immature enabling technologies or missing complementary assets: many products' performance rely on the performance of an enabling technology[56]. When this is low, first movers performance will depend on that of the enabling technology producer, with the risk of having to wait too a long time before the product becomes competitive[57]

If new complementary assets of new technologies are still not available, first entrants could face a low perceived product value. In these cases, entrance should be postponed.

3. Uncertainty of customer requirements: first movers might face great uncertainty regarding which product features customers will like or not and how much they will be willing to pay for them. In this situation, later entrants will free ride on first mover market attempts by adapting the newer product version to the features which have been proven to best respond to market needs.

So as we may see, firms face opposite incentives to enter. Technologies in a too early stage may be unrefined and their market scope uncertain putting early followers in a clear advantage against first-movers. At the same time, letting too much time pass could cause the entrance of many competitors with the risk of finding high entry barriers already in place.

Reassuming the main decisional timing factors will hence be:

1. The uncertainty level of customer needs: higher is market uncertainty over which features the given new product should have, higher first-mover risk, favoring later entry.

2. The new technology performance relative advantage.

[56] An example could be Electric Vehicle's performance dependency on available electric car batteries.
[57] In these cases, first mover bankruptcy is a common event.

3. The maturity level of eventual enabling technologies.

4. The availability of complement assets and their influence on total perceived value.

5. The threat of competitive entry: if entry barriers are already in place or potential competitors lack the necessary technological knowledge, incumbents can wait until the technological and market uncertainty diminish.

6. The presence of learning curves or network externalities in the industry: when these are present, early entrance will translate in the creation of strong barriers to entry.

7. Availability of funds: firms with a larger fund base may sustain a longer period of losses if early entrants, or catch up more easily if later entrants. Firms with limited funds must thus time entrance precisely. Also, funds may be used to market the technology accelerating market acceptance or user education, thus decreasing the risk of early entrance.

8. Firm reputation and credibility: a strong firm reputation can decrease stakeholder uncertainty, making early entrance less risky. Vaporware is a common solution in these situations during the development period, where firms announce extraordinary technological performance, backed by their strong credibility, in an attempt to spur future demand.

9. Technology imitability: higher the degree of imitability, higher will the incentives to wait while other bear R&D and development costs be, with the intention to free-ride on others 'efforts.

Hence weighting the benefits and costs of different entry timings, it becomes evident how what is really crucial in industries characterized by high dynamism and limited windows of opportunity[58] is the capacity of having the right competencies at the right time, in order for firms to maintain[59] their competitive advantage[60].

[58] Abell (1978).
[59] Or create.
[60] Barney (1999).

1.11 Investment and entry strategies

Connected to the decision of which is the right time to enter a market is that of whether to do so alone[61] or by building partnerships with other firms. There are many reasons which may balance the decision towards one end or the other, mainly depending on three factors: a) level of risk and reward the firm is willing to take when making an investment, b) the timing of entry, c) the availability of competencies and reliable partners. The decision may also be constrained by particular situations which limit the choice range[62]. Firms enter new markets by developing the necessary capabilities, and in doing so they may follow four main organizational entry strategies: internal development, acquisitions, market transactions and alliances. The first three imply a solo strategy, while the last a collaborative strategy.

The main reasons for going solo are:

1. Availability of necessary capabilities: the capacity and potential success of a firm pursuing an innovation are proportional to the capabilities and funds available for investment. If the firm does not possess the necessary capabilities, such as specific technological knowledge, it might benefit by collaborating in such a way to acquire that knowledge or by acquiring it externally.

   If the knowledge is missing on the market, the company will have to develop it on its own with risk of taking many years to go to the market. However, if the firm does not possess the necessary capabilities, but aims at building its future competitive advantage on them, going solo could give it better chances of success rather than acquiring the technology externally, through the development of tacit and specific knowledge, which would be difficult to obtain through collaborations.

2. Risk of losing proprietary technology: this can refer either to the risk of a partner managing to acquire your proprietary knowledge during the collaboration or to the willingness of retaining all the benefits acquired by possessing exclusive control

[61] By developing a technology internally, or acquiring it externally.

[62] such as limited availability of funds or applicable knowledge, which would push the decision towards the collaborative edge.

over the proprietary technologies created and their development use. In this context absorptive capacity is of central importance since firms possessing this capability will learn and benefit more from a collaboration at the expense of the partner, and forming collaborations could negatively impact a firm's future success.

The main reasons for building collaborative relationships in innovations instead are.

1. Time concerns: collaborating can significantly decrease the time and cost investments which developing a new technology may require. When complementary assets are missing, time to market can be greatly reduced by importing external knowledge from a carefully selected company.

2. Availability of funds: as in Hagerdoorn et al. (2000), on big project, firms may want to find a partner either to partially hedge the investment risk, or to obtain funds which the project risk profile would make difficult to achieve. Moreover, by forming partnerships to acquire knowledge, firms limit the need to invest capital in a long run project, thus increasing financial flexibility and reducing their cost of capital.

3. Transfer of knowledge: via the network effect, transfer of knowledge is greatly enhanced through the formation of collaborations, increasing the chances of bringing an innovative product to the market.

4. Creating a dominant design: collaborations can be very useful in directing innovations towards a specific path and creating an industry standard. This situation could bring to long lasting monopolistic benefits for the partnering firms.

5. Access to necessary resources: when a technology depends on a resource which is limited or proprietary or inaccessible[63] if not through the formation of a Joint Venture, collaborative decision possibilities will be totally constrained.

However, as seen in Schilling (2013), strategic alliances and joint ventures have gone through many peaks and troughs during history, underlining the mix views of the market towards these means. In fact, even if the pros seem to exceed the cons, when

[63] For example, for Political, Geographical, Monopolistic reasons.

thinking about collaborative strategies, many studies[64] show that managing collaborations is a delicate task and the risk of failure or of one side exploitation can be high.[65]

Expanding the analysis to the different entry strategies as depicted in Figure 3, it may be seen how the strategic decision will depend on the specific situation of the firm and its industry and on different decisional variables. The determinants will thus be the firm's:

1. current position regarding its knowledge and competence base.
2. cash availability and external purchase options.
3. timing of entry strategy and constraints.
4. level of risk-acceptance and commitment to a given investment.
5. need to create a competitive advantage on that given technology

Entry Strategy	**Major Advantage**	**Major Disadvantage**
Internal development	Uses existing resources	Time lag
	Avoids acquisition cost especially if unfamiliar with product/market	Uncertain prospects and high commitment risk
Acquisitions	Saves calendar time	Costly, both to acquire than to reverse
	Overcomes entry barriers	Problem of integrating two organizations
Joint ventures or alliances	Technological/marketing unions can exploit small/large firm synergies	Potential for conflict of interest between firms
	Quicker than developing in-house & less bureaucuratic than hierarchical mode	Loss of unilateral adaptation flexibility
	Distribute risk, commitment & uncertainty	Profits and capabilities have to be shared with partner
Market transactions	High flexibility	Can be more costly than acquisition when exchange uncertainty is high
	Quickest competence acquisition method	Difficult to build tacit knowledge and develop new competencies

[64] Such as from Beamish et al. (2009), Harrigan (1986).
[65] This problem could also be hedged through the use of contracts, which however entail high costs and a lack of flexibility.

Figure 3, representation of different entry strategy modes' advantages and disadvantages.

The many different modes imply that a firm need not to choose just one type when forming an innovation strategy, but can acquire different competencies using any of the different modes[66] based on its current and forecasted future needs.

[66] Even though current research by Gaudillat et al. tends to favor some modes over others for knowledge acquisition. Particularly, market transactions were found to be preferred over alliances when trying to access specific capabilities.

2 The EV Market, Technologies and Investment Strategies.

2.1 The GHG emissions problem.

"After power generation, road transport is the second biggest source of greenhouse gas emissions in the EU. It contributes about one-fifth of the EU's total emissions of carbon dioxide (CO2), the main greenhouse gas."[67] Furthermore, over the past 20 years it is one of the few sectors where emissions have been rising rapidly, increasing by 22,6%. To make things worse, world transport is currently dependent by 95% on fossil fuels.[68] Reaching both energy sustainability and climate protection requires a transition from a petroleum-based transportation system to one dependent on a mix of electricity, hydrogen and biofuels[69], produced through high efficiency-low GHG emission technologies. How to accomplish such a transformation in an economically efficient-environmentally effective way, is as of today, one of the biggest debates and challenges concerning public policy and private action.

One of the reasons for making this such a difficult task is that the primary motivation for the transition is to secure public goods: environmental protection, energy security and sustainability (Greene, 2010) and such a major transition may take decades with the result of having the possibility to see its lasting results only in a distant future (Gallagher et al. 2012). Moreover, there are some important market shortcomings such as the tendency of financial markets to undervalue energy efficiency[70], which create incentives to continue operating with inefficient energy sources.

Despite all these issues Governments are starting to take action in an attempt to start this energetic revolution. California's ZEV[71] mandate represented one first isolated attempt at solving the problem. Recently, world governments have managed to follow the lead and set some common standards.

A clear example is that representing the EU's situation. After a one-year extension obtained from the German automakers, the EU managed to set a mandatory reduction

[67] European Commission Press Release Database
[68] IEA (2012).
[69] NRC (2013).
[70] Jaffe et al. (1994), Sanstad et al. (1994).
[71] Zero-emission vehicles.

target for all new cars produced by OEMs. This was mainly due to the fact that the latest improvements in fuel efficiency have not been enough to balance the increase in traffic and car size, resulting in an increased CO2 balance, offsetting the Union's efforts at decreasing emissions. The main objective of the legislation is that of inducing automakers to invest on fuel economy improving technologies for cars sold in the EU. Examples of these new technologies are alternative powertrains and fuel sources, new light materials, aerodynamics, mechanical and combustion engine improvements. Improvements translate in lower well to wheel[72] efficiency and lower overall GHG[73] emissions (including CO2).

By 2021 the fleet average CO2 emission has to decrease from the actual 130gr per km to 95gr per km. This would translate in an average fuel consumptions of 25 and 27 l/km for petrol and diesel cars respectively. Fleet average weighted emissions will be calculated using a limit value curve which requires higher improvements for bigger cars compared to smaller ones, leaving however the possibility of producing cars emitting more than 95g/km.[74]

The precise formula for the limit value curve will be:

Permitted specific emissions of CO2 = 130 + a × (M − M0), where a is a fixed parameter, M is the mass of the vehicle in consideration and M0 fixed mass parameter[75].

Hence, heavier cars will be granted higher CO2 tolerance, entailing higher CO2 targets for big car manufacturers, resulting in different targets for each car manufacturer, as seen in Figure 4.

According to a study from PA Consulting Group, which compared the actual and forecasted emission performances with the specific company targets[76] for 2021, 4

[72] Also known as Life cycle energy analysis (LCEA) is an approach in which all energy inputs to a product are accounted for, not only direct energy inputs during manufacture, but also all energy inputs needed to produce components, materials and services needed for the manufacturing process.
[73] Green house gas
[74] Balancing the emission score with low emitting cars and allowing for higher emission proportionately to the car mass.
[75] A=0,0457 and M0=1289kg.
[76] Calculated according to the forecasted improvement and future fleet mass weighted average.

major car manufacturers will likely not meet their target, and cumulative fines could reach €2 Billion.[77]

If car manufacturers do not innovate and improve fuel efficiency enough by 2021, a tax[78] of €95/g of CO_2 above their limit will be imposed. For the first 4 years, low-emitting cars will have a heavier weight[79] in an attempt to push the introduction of alternative fuel vehicles. Putting the penalty into context, if a large car producer[80] which has a current average fleet emission of 123g CO_2/km, managed to reduce emissions to 98,8 g[81] CO_2/km it would have to pay an estimated €1,24 billion fine per year to the EU.[82] If foreign countries adhered to the emissions cap, the fine could be considerably higher. To further promote investments in efficiency innovations the EU grants automakers introducing eco-innovations whose effects cannot be directly demonstrated during vehicle testing[83] emission credits[84] over the 95g limit. The rules apply for all automakers with some exceptions.[85]

[77] PA Consulting Group (2016).
[78] Excess emissions premium
[79] Super-credits for vehicles with emissions below 50g CO_2/km.
[80] Such as Volkswagen with 1,7 million new cars sold in Europe.
[81] Forecasted 2021 emissions.
[82] (98,8 - 95,9) x €95 X 4,5 M cars sold (in Europe in 2015).
[83] Whose positive effects have to be however verified by an independent agency.
[84] For a maximum of 7g/km per year.
[85] Smaller manufacturers have different emission targets according to number of vehicles produced.

How carmakers rank on CO_2 emissions

		Actual data (g CO_2/km)			PA forecast (g CO_2/km)**			(g CO_2/km)	
Rank*	Carmaker	2010	2012	2014	2015	2018	2021	2021 Target	Deviation
1	PSA (Peugeot Citroen)	131.6	121.2	110.0	103.7	97.9	85.2	86.9	-1.7
2	FCA (Fiat Chrysler)	125.9	119.8	116.5	112.2	103.4	88.0	89.1	-1.1
3	Renault-Nissan	138.9	126.2	113.5	111.8	105.1	89.6	91.6	-2.0
4	Toyota	130.0	121.7	112.8	110.1	101.7	90.9	93.4	-2.5
5	Ford	136.9	129.1	121.6	118.8	109.9	94.9	93.6	1.3
6	General Motors	139.8	132.4	130.5	126.0	115.2	95.5	93.8	1.7
7	Hyundai-Kia	139.0	134.0	130.5	130.1	118.5	98.8	94.3	4.5
8	Volkswagen	142.5	133.5	125.8	123.5	114.9	98.8	95.9	2.9
9	Volvo	161.0	144.0	126.5	123.9	117.1	99.8	100.3	-0.5
10	Daimler	163.3	147.8	131.5	129.6	119.9	103.2	101.6	1.6
11	BMW	147.9	140.9	131.7	130.4	122.9	103.3	100.9	2.4
12	Jaguar Land Rover	223.0	187.0	178.0	174.2	157.5	135.7	132.0	3.7

*on 2021 forecast. **based on actual data until 2014.

< 0 0-2 > 2

Figure 4, source: PA Consulting Group Report

To summarize, by 2021 all automakers will have to improve their current fuel efficiency not to incur in a EU penalty. The EU's main aim is to improve the Well to Wheel and local GHG emissions in such a way to reduce transport pollution levels. To improve efficiency car makers must invest in lowering their average fleet mass and promoting their alternative fuel vehicles, which could considerably cut their weighted average emissions[86]. According to the EU Climate Action Commission this would finally translate in fuel cost savings[87] for final users, which should compensate for any eventual increase in purchase price. As can be seen in figure 5, similar regulations are under consideration worldwide, with U.S. setting a 93g limit by 2025, and China sharply tightening its regulations. The consequences will be similar to the ones already explained further increasing the scope regulations will have on automakers in the following year.

[86] Some car manufacturers have a current EV (Electric vehicle) / CE (Combustion engine) market share of 0,1%. Electric vehicle sales must increase steeply in order to have a significant effect on total fleet emissions.

[87] A 27% fuel consumption forecasted saving, which equals a €2904-3836 saving (depending on the price of fuel) over the car's lifetime (13 years) for the average car type. Net cost life-time savings subtracting the price surcharge would average €2000 per car (EU Climate Action forecasts).

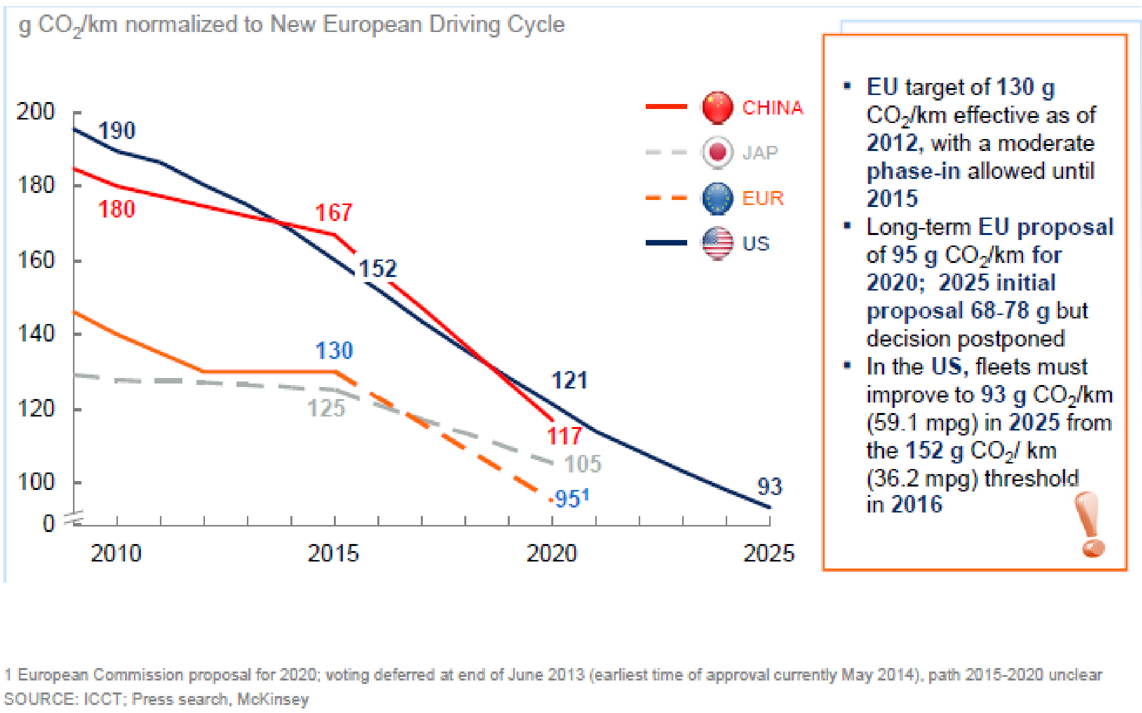


Figure 5, Source: McKinsey Evolution report (2014).

2.2 The technology S-curve and ICE engines

Following the introduction of tighter emission standards and the change in the emission test procedures[88] automakers have been put under pressure to increase the efficiency of their IC engines in order to reduce CO2 and NOx emissions. This has led to a reconfiguration of petrol engines and to heavy investments on the diesel units. Of the two however, the latter needs greater improvements for what regards powertrain NOx emission requiring higher costs due to the already high levels of efficiency reached. To reach the standards, investments will be made in powertrain improvement, engine reduction, vehicle weight, aerodynamic drag, rolling resistance and hybridization development. However due to the maturity of the technologies and their high levels of performance the emission control costs[89] and the emission reduction potential are represented by a non-linear function as seen in A.D.L.'s 2016 report[90] and depicted in Figure 6. These higher requested improvements will require

[88] Due to the flaws in the old tests exposed by the emission scandals.
[89] Efficiency improvement investments
[90] The future of diesel engines report by Arthur D Little (2016).

higher investment costs for diesel with regard to petrol engines. The two engines will remain competitive however once considering their TCO. However, due to the continuously increasing improvements costs, these powertrains are expected to lose market share progressively. In fact, data from 2016[91] shows how it has been the year with the smallest improvement in engine emissions in the past 10 years and that diesel engines in Europe[92] are decreasing. Investments in alternative powertrain innovation will be needed to find new solutions with greater improvement potential per $ spent. In this direction seems to be going Volvo, which according to its CEO H. Samuelsson, even though has its sales mainly based on diesel engines, will abandon investments in that technology after 2021 due to improvement costs being too high compared to an electrification or hybridization of its powertrains.[93]

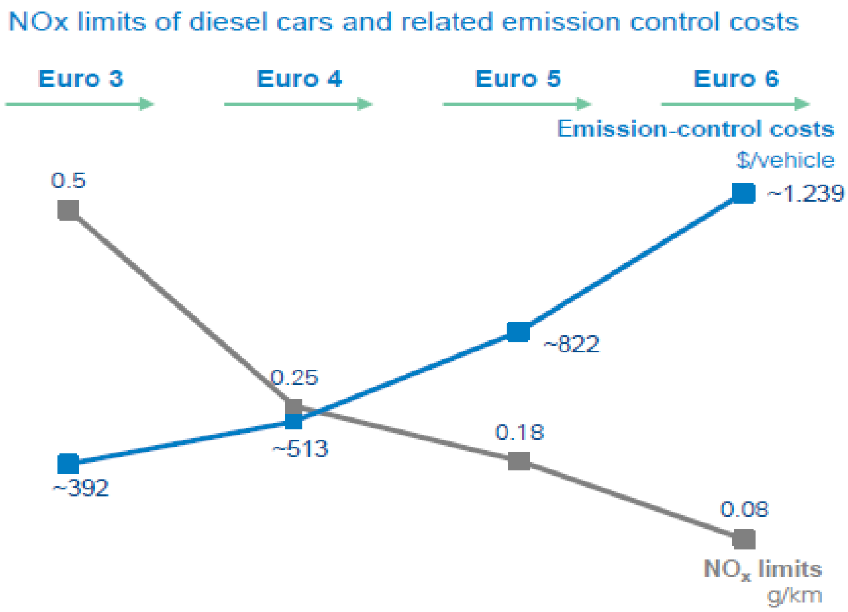


Figure 6, Source: A.D.L. report (2016), The future of diesel engines.

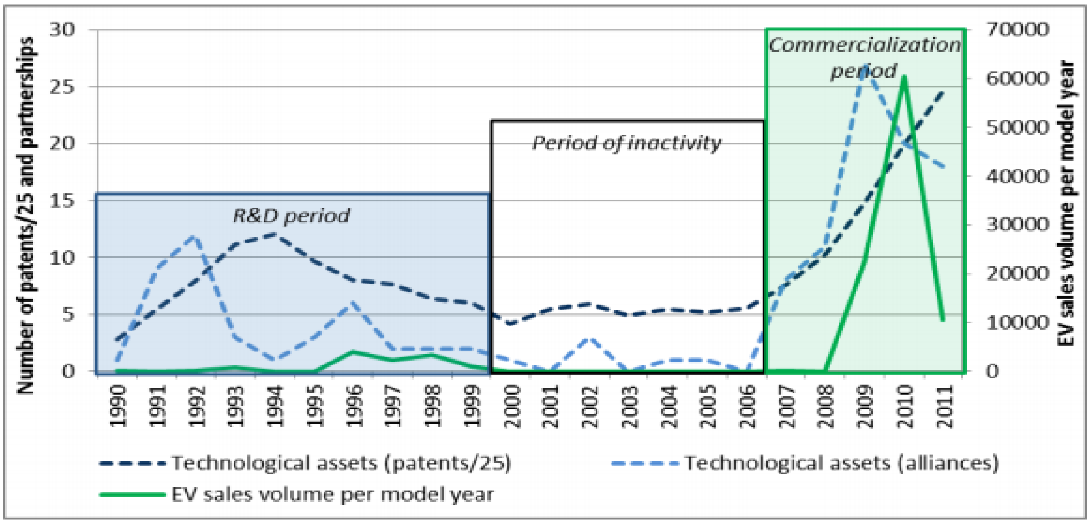
Even if constrained by government regulations, the huge amounts of money spent in powertrain improvement R&D also come with some benefits, as can be seen by the

[91] Retrieved from Quattroruote.it
[92] The world's greatest Diesel market for vehicle market share.
[93] Retrieved by an interview to Reuters, found on an article by Quattroruote, May 2017.

positive relation between fuel economy increases and increase in sales for the year 2013[94].

2.3 The past & actual market, and future EV market forecasts

Figure 7 by Wesseling et al. (2015) shows the established automakers' R&D and commercialization efforts during the period 1990-2011. As can be noticed, after an initial period of ferment from 1990 to 1999 during which there was a surge in R&D investments and collaborative alliances, a 7-year gap developed during which EV research and activity highly diminished, leaving the technology almost dormant. A last period from 2007 up to present shows a steep increase in EV related technological assets and patents following a revival in R&D efforts and collaborative ventures. Proportionately to the R&D efforts, it may be seen how EV sales slowly grew in the first period, totally dropped in the second and surged in the third following the revived interest and belief from some car manufacturers that EVs could become a commercially viable opportunity (Magnusson et al. 2011). This last time-frame has been labeled as the start of the EV commercialization period for most automakers.



[94] Data from Marketrealist.com show how Nissan and Subaru who registered the highest growth in fuel efficiency also showed the highest sales growth with an outstanding 13 and 21% respectively against and industry average of 5,9%.

Figure 7, Source: Wesseling et al. (2015), Trends in R&D and commercialization over the period 1990-2011.

The year 2016 saw the global threshold of 2 million electric cars[95] on the road, with an annual record of 774 thousand units sold. Put in perspective, this is a huge number compared with the few thousands of 2010. The main markets accounting for more than 80% of annual sales are China, US, Norway, Netherlands and Japan, with the first two weighing the most in terms of sales, and the third weighing the most in terms of EV market share on annual car sales. This market concentration is an important element to analyze since it demonstrates how EV diffusion can be determined by just a few countries on one hand, and how volatile it can be on the other, due to its dependence on just a few markets. Ambitious emission targets and strong policy support have determined the EV boom in a number of countries, such as China, US and Norway. The latter having the highest state subsidy per car. China is the largest market not only for EVs, but also for e-scooters and buses, following the Government's effort at reducing extremely high local pollution levels.[96] This point highlights another fundamental aspect of the EV market, which is its current dependence on policy support to achieve widespread adoption. There is in fact, as can be seen in Figure 8 a positive correlation between strong policy support through direct and indirect incentives and the diffusion of EVs in a given country. Policy support has to be also directed towards supporting the recharging infrastructure due to the complementary relationship and the self-reinforcing principle. The two markets need to grow together and government intervention has been fundamental in many countries, especially for what regards the fast-recharging infrastructure.

[95] 2,046 million electric cars including BEVs, PHEVs and FCEVs (EVvolumes annual sales report).
[96] Source: International Energy Agency, Global EV Outlook 2016.

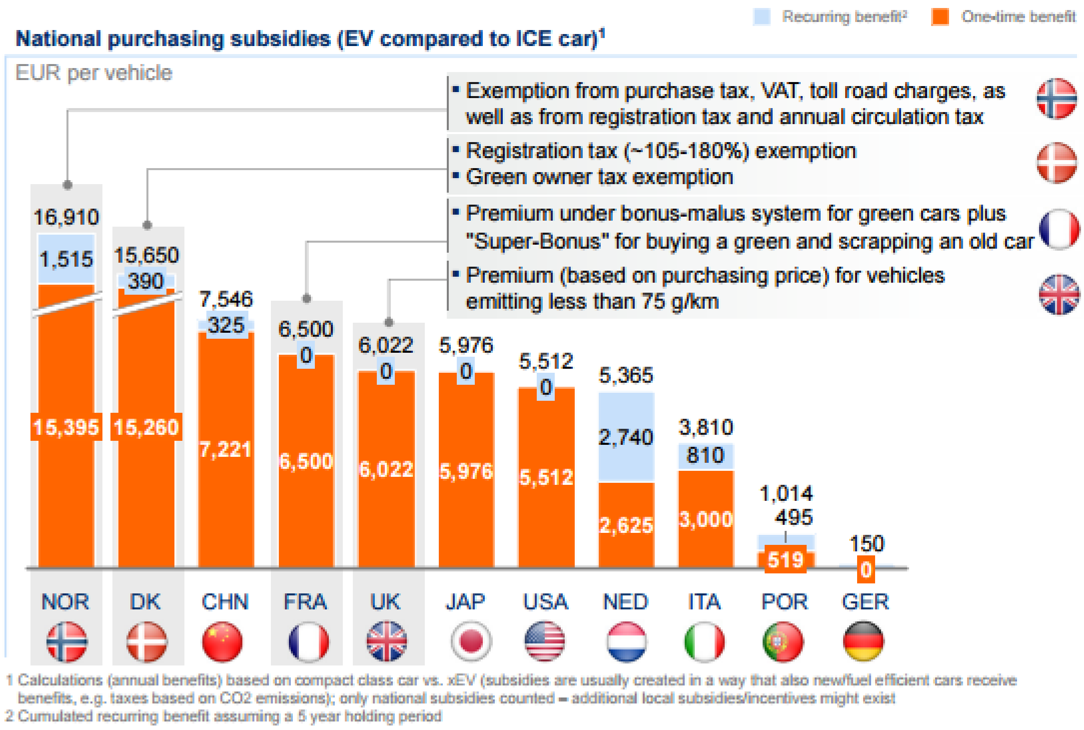


Figure 8, Government EV subsidies in 2014, source: McKinsey Evolution Report.

Adding to the 2021 emission targets, other international sustainability targets have been set[97] in order to limit the global average temperature increase to 4°C by 2030[98] which would require a much stronger EV market growth than forecasted, which would be only possible thanks to a strong international policy support.

Even though actually EVs only have a market share of 0,86% globally[99], the future development of the automotive industry is very uncertain. In fact, all these different targets and the insurgence of stricter political regulations add up to uncertain oil prices, the sudden entrance of new competitors[100] and changing consumer demands[101], putting car manufacturers in a period of great ferment and pressure. The market is showing the first signals of a need that will ultimately result in a huge industry change brought by an inevitable disruptive innovation. Which innovation will

[97] The EVI 20 by 20 target calls for an electric stock of 20 million by 2020, while the Paris Declaration on Electro-Mobility and Climate Change set a global target of 100 million electric cars and 400 million e-scooters on road by 2030 (EV Global Outlook 2016). The first target being difficult to reach with the current sales figures.
[98] The IEA 2DS which has a more optimistic 2°C target (with 50% chance) by 2030 requires a 150 million EV stock by 2030.
[99] Source: EVvolumes.com
[100] Tesla's market value overtook Ford's and GM's at $59,23 Billion as of 07/06/2017.
[101] Consumers are becoming more and more concerned about Environmental aspects.

become the dominant design and when will the real change happen is what most manufacturers are trying to understand, and in this period of indecision, some have already invested heads-on following what they envision the future will be.

In this context, EV market forecasts are fundamental as they are needed in order to make a correct innovation strategy and in deciding the right timing of entry. Market forecasts envision different annual market shares based on the underlying assumptions taken. Worthy of notice is Bloomberg's New Energy Finance report which forecasts a 35% annual market share for 2035, equal to about 41 million EVs sold, with the real take-off time being around year 2025, as seen in Figure 9.

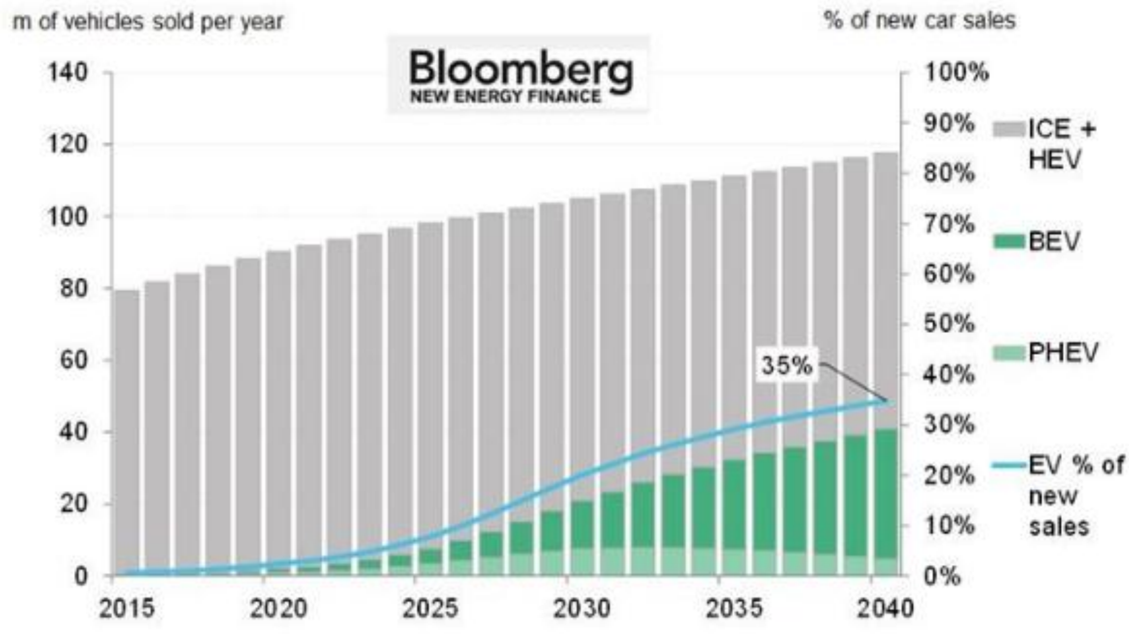


Figure 9, source: Bloomberg New Energy Finance Note. Global LDV and EV yearly sales, 2015-2040 (m vehicles sold per year, %).

An alternative report made by McKinsey (2014) stresses how much Government actions could way on the future diffusion of alternative powertrains, forecasting EV market shares under 3 different scenarios. The scenarios are mainly dependent on what future emission limits will be set for 2030 and 2050 by the major World Leader Governments. As can be seen in Figure 10, Government regulations could alter the future path of technological innovations by creating distorting incentives on the different technologies.[102] By internalizing the externalities of ICEs[103], the lower the level of tolerance[104], the faster and larger will be the diffusion of full EVs compared with Hybrid versions, and the faster will be the demise of ICEs. This relation will be mainly due to the technological limits of ICEs, whose emissions cannot decrease as fast as those promised by EVs per $ of investment spent. Thus increasingly stricter regulations will make Electric powertrains the only viable solution.

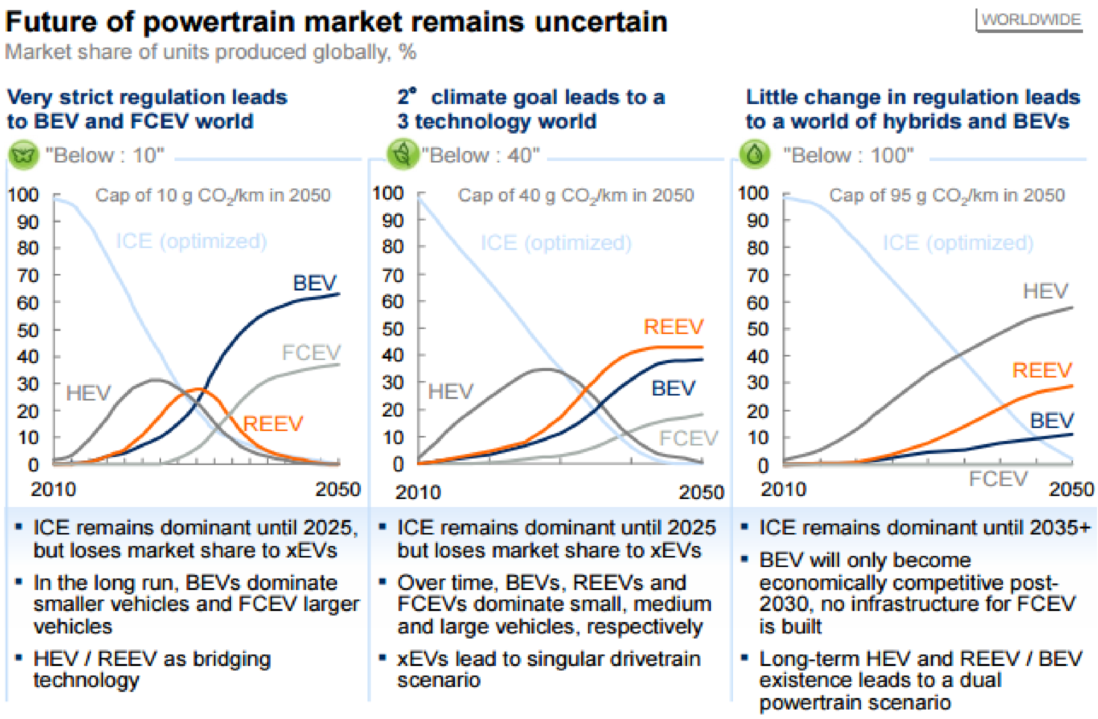


Figure 10, source: McKinsey Evolution report (2014).

Other noticeable sources such as Goldman Sachs forecast a 22% market share, including conventional hybrids, by 2025[105], while the IEA 450 scenario shows a 30% market share by 2030[106]. To conclude, other projections[107] forecast sharply differing market shares for EVs based on strong, moderate and weak government policies, with 2035 market shares varying from 85 to 17%. This report is similar to that suggested by McKinsey, highlighting the importance of adequate Government Policies when

[102] Il Sole 24 ore suggests a 66% EV Market share by 2030 if emission limits reach 50g CO2/km.
[103] Internal combustion engine
[104] Stricter emission standards.
[105] Goldman Sachs report (2015).
[106] IEA 450 scenario.
[107] From Adam Whitmore, independent energy advisor.

considering Environmental action. Not all reports however are so optimistic about the future for EVs, in fact, according to a JP Morgan report[108], most of the projections made up to now have been erring on the high side and should be revised accordingly, as seen in Figure 11. Since the technology is still in its initial phase, lowering future projections would translate in retarding the expected diffusion to the mass market.

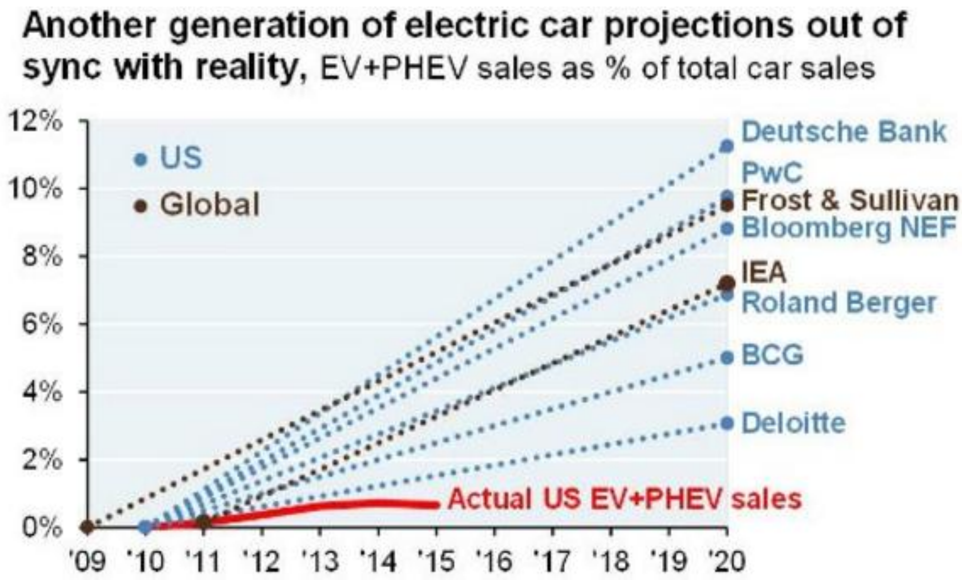


Figure 11, source: Electric cars: the 1% solution? (2016).

2.4 The different powertrains taken into consideration

Today's car powertrains, defined as the main components that generate power and transmit it to the road surface can be roughly divided in five types: ICE, HEV, REEV, PHEV, EV and FCEV.[109] The main difference among the various systems[110] are the main source of propulsion and the energy generation sources.

Figure 12 briefly summarizes the main differences among the various powertrains showing what a current portfolio of EV cars could be in a car manufacturer's fleet.

[108] Electric cars the 1% solution? (2016) by Michael Cembalest.
[109] Internal combustion engine, hybrid electric vehicle, plug-in hybrid electric vehicle, electric vehicle and fuel cell electric vehicle.
[110] Without considering the internal mechanics, which greatly differ among each other, especially for what regards the conversion of energy in electricity or internal combustion to fuel the motor.

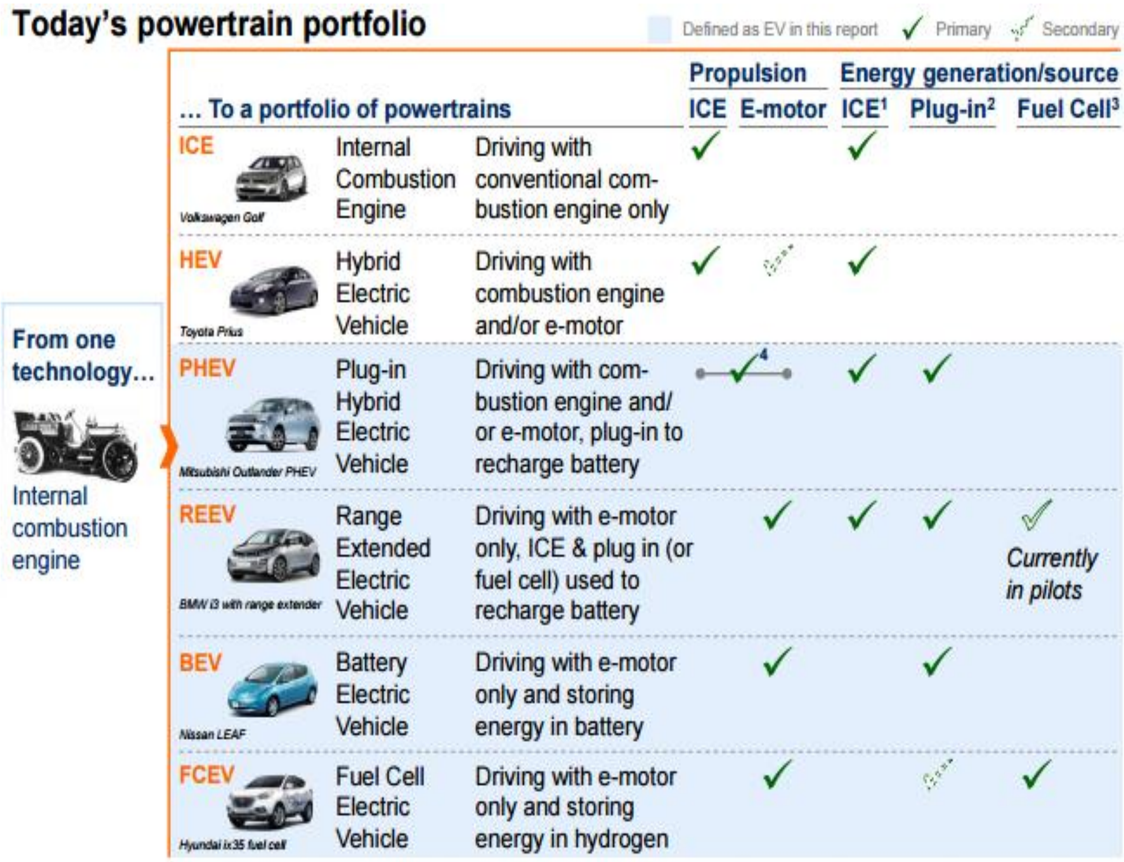


Figure 12, source: McKinsey Evolution report (2014).

As can be noticed, the different propulsion systems have differing benefits and costs with all the hybrid version representing a middle road between ICEs and BEVs/FCEVs characteristics.

Comparing the different powertrains, we can see what the relative advantage of each is:

1. ICE's main advantages are its competitive cost, technological maturity and reliability, extensive supply network, proven performance and high autonomy range. Its main drawbacks instead are the limited space for further improvements, its low well to wheel efficiency compared to other propulsion systems and high emissions.

2. HEVs and PHEVs on the other hand present reduced CO2 and pollutant emissions due to the battery cruise possibility, lower consumption on short trips and a more efficient propulsion system respect to ICEs and a higher autonomy range compared

to full EVs. Moreover, they can rely on the existing fuel infrastructure in combination with plug-in options for PHEVs. These benefits are balanced by a heavier powertrain, technical complexities, a disproportionate high price respect to ICEs, a very low battery range and higher emissions with respect to full EVs.

3. EVs have a high WtW efficiency coupled with zero local emissions. Depending on the battery set and engine they may also present outstanding performance and torque levels compared to ICEs. However, they have the most limited autonomy due to battery only propulsion, have the heaviest battery packs, are dependent on an underdeveloped, but growing, charging infrastructure and are very high priced. Moreover, refueling takes long even with the fast charge option (which is still absent in many cities).

4. FCVs present the highest WtW energy efficiency coefficients and produce zero local emissions. Opposed to BEVs, they potentially have a very high range and a very low refueling time. However their technology is still underdeveloped, hydrogen production can be very energy-intensive, their specific recharging infrastructure is still inexistent and due to their technological complexity are tagged with a price too high for the average driver.[111] Moreover, following the fact that technology is very path dependent, the limited attention it is attracting from a few forward looking car manufacturers could postpone its diffusion or halt it altogether.

2.5 Brief summary of factors affecting EV adoption

2.5.1 EV Demand diffusion fundamental variables under Roger's model

As can be seen from the potential powertrain portfolio, car manufacturers have a wide array of options on which to invest and from which to market. Each manufacturer's innovation strategy will then depend on their forecasted future vision, since the diffusion of one or another technology will make the difference between future profits

[111] The Toyota Mirai, a 154 hp sedan is priced at €66 thousand (excluding taxes).

and future losses. Furthermore, not only will the right technologies have to be chosen in order not to lose competitiveness and industry market share. The right timing of entry will also be a fundamental decision, as a too early or late entry on a given technology could a cause market flop due to low demand, or an overcrowded competition.

Understanding which are the main variables which affect each technological diffusion and how these variables will change in time is fundamental in order to make the right strategic decision.

Following Roger's decisional factors as seen in **1.6.1** we find at present for BEVs and FCEVs that:

1. Relative advantage: compared to ICEs the main advantage of EVs is represented by the production of 0 local emissions a high torque and performance potential [112], driving pleasure and noise, and a positive image.[113] Moreover, EVs are seen as more technological with respect to the classic ICEs. However, this is balanced by several factors which at present could net to a negative value for EVs.

These are:

1) The charging infrastructure availability and charging time: the charging stations are the main BEV complementary asset, are positively correlated with EV diffusion[114] and are currently underdeveloped. A sufficiently available charging infrastructure is necessary to guarantee EVs mobility and reduce owner range anxiety.[115] For FCEVs the infrastructure is almost non-existent[116]. To improve the infrastructures government intervention can be of fundamental importance, especially for promoting investments in the fast charging

[112] As already seen in 2.1 emission regulations are correlated with adoption as they force automakers to invest on increasing the EV performance and availability.
[113] Hulsmann et al. (2013).
[114] Sierzchula et al. (2014),
[115] Depending on the kW power levels it can be divided in slow (4-8 hrs) and fast (20-30 min), with the latter's diffusion being much more limited due to high infrastructure investment costs.
[116] "The hydrogen infrastructure problem is a classic "chicken-and-egg" issue: companies will not invest in infrastructure without a significant FCV market, and FCVs are not viable without an adequate level of infrastructure" (ADL report 2017).

network[117]. Charging time is also fundamental, since the wider the charging time gap among powertrains, the lower the relative advantage. In this context the fuel cell's similar recharging time (comparable to ICEs) and long range capacity would make FCEVs the perfect substitutes of ICEs for long range commuters. EVs lag behind, especially when using the slow charging towers.[118]

2) Battery driving range and cost: the two variables are interconnected since long-range batteries require a high power density and are the highest cost component in an EV[119]. Smaller batteries come at a lower price, but do not resolve the range anxiety problem limiting their use to intra-urban areas. At the moment battery relative performance[120] is still low when compared with ICE, even though it is expected to become competitive in the next 15 years.[121] The same applies for FCEVs since fuel cells are currently prohibitively expensive, with the distinction that their premature technology will take more time to become competitive with ICE, even though they have the considerable benefit of being way lighter compared to EV batteries. Moreover fuel cell batteries have a much longer range and can be stacked making the fuel cell alternative scalable and thus more appropriate for larger vehicles with respect to pure electric batteries.[122]

3) Purchase price: is maybe the most important factor for public acceptance of new vehicles since their performance is valued with respect to their price. At the moment the price gap between EVs and ICEs is substantial and will continue to be so for the next 20 years. What must be stressed is that even though the purchase price gap is high due to the initial battery cost, the TCO[123] narrows the gap which will be closed or inverted by 2030. In this context

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[117] Which requires high investment costs, but is positively correlated with reducing range anxiety and increasing EV adoption.
[118] Which can take 4-8hrs or more depending on kW power.
[119] Sources: US DOE (2016), EV Obsession (2015).
[120] With respect to cost
[121] According to BNEF the cost of batteries will decrease dramatically between 2020-2030 making the EVs less expensive than ICEs when considering the TCO (total cost of ownership).
[122] Source: ADL report: What's in the future for fuel cell vehicles? (2017).
[123] Total cost of ownership

Government monetary incentives are of great used as they can narrow the price gap and induce more potential adopters to pick EVs[124].

4) Cost of fuel: relative TCO is proportional to the price of fuel for each different powertrain. In this respect, a low future oil price will retard the adoption of EVs and FCEVs and vice versa. However, fuel cells depend on hydrogen which could be very costly to produce[125], further retarding FCEVs diffusion.

5) Durability: calendar life gap of EVs with respect to ICEs has to narrow in order to make the alternative powertrains systems more compelling and competitive, especially since changing a battery pack can represent a substantial financial burden.

6) Low model availability: this only represents a temporary disadvantage as all major OEM manufacturers have announced the release of EV models in their product portfolio.

2) Compatibility: an EV should be considered compatible if it can be used in in everyday life without restriction. Average weekly travel profiles and personal car use are the main measure with which potential adopters value how compatible are new adoptions with their current lives. The main take here is how perceived compatibility could affect the decision. Since notwithstanding the EV compatibility with the use of most average drivers, they might perceive having a different driving profile or might want to be flexible regarding their future car use. In this context, FCEVs are at advantage with respect to EVs, while the latter might be badly perceived due to the limited driving range. Personal values[126] might also be central in the adoption decision, since drivers concerned about the Environmental issue could perceive an EV as an "attractive and sustainable means of transport" (Hullsman et al. 2013).

[124] The positive correlation is once again demonstrated by Sierzchula et al. (2014)
[125] Production through electrolysis is greener but very costly and inefficient at present, while conversion from natural gas would represent a less renewable, but less costly alternative.
[126] Skippon et al. (2011).

3) Complexity: once again a distinction must be made between perceived and actual complexity, with different studies[127] arguing how consumers who have not had the chance of testing an EV might perceive the new technology as being more complex than an ICE powertrain, while it might not be so[128].

4) Trialability: due to the evolving but actually limited product offer, trialability can be considered to be low but increasing. As for the infrastructure presence, product range greatly varies from country to country. Moreover, a distinction must be made between low and high power battery supplied cars as the driving experience greatly varies between the two, and the trial of one kind is not representative of the other. Trials are fundamental in the car industry and must be pushed by the dealer network for EV diffusion as many studies demonstrate how EV trial greatly increased vehicle acceptance and enthusiasm.[129]

5) Observability: as for trialability, observability might be perceived as relatively low but increasing due to the limited expanding stock of EVs on road. However, as demonstrated in a study from Carroll et al. (2010)[130], since the real value of cars can only be perceived through trial, observability might not be as important as trialability for EVs.

So, as can be seen, at present the EV technology is still far from maturity and this heavily impacts its current adoption. Given the current sales figures[131], the average driver's cost benefit analysis must still be favoring ICE over EVs. This means that the current advantages[132] do not exceed current costs[133]. Especially high purchase prices must be currently limiting sales, especially for smaller cars where in comparison the e-

[127] Hulmann et al. (2013), McKinsey Advanced industry report (2017).
[128] Knie et al. (1999) suggest that EVs might be simpler to drive as they do not have a gearshift.
[129] Skippon et al. (2011), CABLED (2010), Knie et al. (1999).
[130] Who surveyed 42 participants before and after an EV test drive finding that purchase intentions greatly increased with trials, as fundamental attributes such as acceleration, top speed, and performance highly exceeded their misconceived prior expectations.
[131] 1% market share.
[132] As seen in Lebeau et al. (2012), these mainly are being ecologically beneficial, having low running costs, a swift acceleration and low noise emission.
[133] Always from Lebeaut et al. (2012), these are the high purchase price, limited driving range, lack of charging infrastructure, battery longevity.

version can cost twice as much as the gasoline one..[134] Moreover, as of today, drivers have many misconceptions regarding the complexity, performance and trustworthiness of alternative powertrains further delaying its diffusion. This last point is important, since EVs are not very attractive, not only because the benefits of "no pollution"[135] are in conflict with the high costs of ownership, but also due to these numerous misconceptions[136] regarding EV quality and price[137]. In fact, if this were the case, increasing user information could greatly increase the probability of adoption. A clear example, as seen in Franke et al. (2012) would be the range anxiety[138] problem according to which drivers perceived the limited battery range[139] as a problem, even though their daily commute was 40 miles.

A study by Welzel et al. (2013)[140] found that out of the 5 factors, the ones having the most weight were relative advantage, trialability and compatibility, with the latter having the strongest impact. On the contrary ease of use and observability were shown to have a minor influence with respect to the first. Additionally, they identified Innovators or Early adopters as being male, wealthy, environmental concerned EV informed drivers. This seems in line with expectations of a possible Lead user of the product, since Environmental friendliness is one of the main positive attributes, and high prices are one of the main concerns. Moreover, innovators already have a significant knowledge of the product being tech-friendly, greatly decreasing the misconception bias.

A study by Emsenhuber (2012) confirms how at present the only motivating factor for choosing an alternative powertrain is environmental friendliness while purchase price and driving range were actually deterrent factors. However, this should change with time, possibly turning the current situation upside down. Emsenhuber also found how socio-demographic factors influence the decisional choice with factors such as family

[134] The e-up! is priced at €27850, while the similar gasoline version is price at €14000.
[135] Which are mainly societal, generating positive externalities.
[136] Perceived complexity, performance etc.
[137] TCO is a better price comparison than purchase price for alternative powertrains, due to their initial higher costs, and lower running costs.
[138] Fear of becoming stranded
[139] Today the Chevrolet Bolt, a $37k EV has an estimated EPA range of 238 miles.
[140] Who used a regression analysis to calculate the weight of each of Roger's five decisional factors.

status, educational background and age being significant predictors of the adoption choice.

From the perspective of established firms instead the main variables will be the threat of industry disruption[141], the investment requirements and the expected ROI. This can be clearly seen in the current situation of the automotive industry, where many players have suddenly awaken following the insurgence of a clear menace.[142] However even if the opportunity is present, most players are making only partial commitments due to the high investment costs and the expected low ROI.[143]

As stated by the Peugeot-Citroen-DS Group CEO[144]: "I don't think an EV will be profitable in the near future. Not unless you can sell the battery on to a second use. […] We don't know how much customers will pay. And other fundamentals haven't been fully studied." Following this logic and the potential EV cannibalizing effect, it is easy to understand how traditional ICE manufacturers will be willing to maintain the status quo and postpone the EV diffusion as much as possible.[145]

2.5.2 The difficulty and importance of surpassing the Chasm

Welzel et al. (2013) always found that contrarily to innovators, potential early adopters are described as a big group of users who have some interest in alternative powertrains, but do not have enough knowledge about them, do no not have the required financial availability and are not as interested in being technologically innovative.[146] This means that the early majority target is fundamentally different from that of lead users, following a different logic and responding to different stimuli. It is important to notice however, how differently from Moore's assumptions[147], in the

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[141] Until the menace is not defined, incumbents tend not to divert from their current business model maintaining their state of inertia.
[142] Emission penalties and the risk of late market entry, with the consequence of being disrupted by new entrants.
[143] Many automakers expect making a loss on the first EV model releases
[144] Carlos Tavares
[145] If it was not for external threats which create incentives to innovate. Moreover, differently from most of the automakers, VW group stated how they expect their EVs to be profitable starting from the first introduced to market.
[146] Welzel et al. find that for the average driver, environmental benefits, a main purchase motif for early adopters, is not so important, especially when compared with the costs related to owning an EV.
[147] Moore (2014).

case of EVs, the problem of innovators wanting to keep the technology exclusive is reduced, since all users would benefit from the innovation diffusion due to the complementarity and compatibility effects.

The above points confirm the precedent analysis following Roger's decisional factors and imply that two big actions have to be enacted in order to access the early majority and push the technology though the chasm. Firstly up-to date, clear information has to be spread to the potential market in order to decrease misconceptions and improve the perceived products' relative advantage[148]. Marketing campaigns addressed to specific target users can prove particularly beneficial. Secondly, purchase price and TCO has to decrease in order to attract the larger user base. This can be done by either decreasing component costs via the learning curve effect[149] , or by maintaining or increasing[150] Government purchase incentives until the price gap diminishes, or by finding new business models which better appreciate the EVs' unique value.[151]

Late majority individuals are similar to the previous with the difference that they lack any sort of innovative drive and wait for a product to become mainstream, hence reaching a reasonable level of trustworthiness before opting for its adoption. These drivers will likely become adopters by imitation, once the user base becomes large enough as to bring the development of its complementary assets close to maturity. At this point in time, battery costs will have sufficiently decreased aligning EV prices with those of similar ICE models. Moreover, the possible compatibility will be maximum as all needed structures will be developed. Knowledge about the technology and its' ease of use will be extended and trialability and observability will become comparable to those of ICE vehicles.

Laggards will be that customer group persistently refusing electric vehicles due to their personal negative perception about these alternative powertrains. They will be very hard to convince, since they show a negative attitude towards the unique attributes

[148] Customer training is fundamental until the chasm is not overcome.
[149] Which would imply a sufficient production mass is reached.
[150] Where not sufficient
[151] The EV price gap could be greatly decreased by maximizing car running time, thus fully utilizing its lower running cost potential. A clear example could be the car sharing alternative, thanks to which the higher purchase price would be easily recovered through savings on running costs.

possessed by EVs and will opt for adoption only when the relative advantages of owning one will become particularly high. However, at this point in time, late majority and laggards are of little interest due to their adoption dependence on sociological factors and the impossibility to attract them at present. Managers should try concentrating on the first two user segments, who greatly value the technology and the environmental benefits in an attempt to push the EV diffusion to reach the critical mass.

What should worry automakers at present is where they think the EV market is placed in time and most importantly when they hypothesize the chasm will occur. Being ready to enter at the right time will be crucial for most companies. In addition, Lempert et al. (2006) found that in these situations of deep uncertainty regarding the future development of a technology and its market, companies should try to pursue robust and adaptive strategies based on the forecasted situation, as they were found to be superior to fixed strategies based solely on a best guess approximation of what the right choice could be.

If we assume the potential long-term market share for alternative powertrains to be equal to that currently belonging to ICEs, comparing Roger's adoption rates to the current EV market share[152] it can be seen how the market is still in the innovator phase. With a current market of 90 million vehicles sold annually, in order to reach the early majority phase, the EV annual sales have to reach the 14 million figure. Applying the average growth rate for the period 2012-2016[153] the 14 million target should be reached by the year 2023[154]. However the diffusion curve should become steeper when it reaches the early majority phase implying a higher sales growth for the period 2023-2035[155].

Following this analysis, the chasm could occur in the period between 2020-2025 after some main event shocks the automotive industry. Two examples could be the big

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[152] 0,86% market share in 2016 equal to 773, 600 sales (Plug-in + full BEVS) not considering FCEV whose sales are still irrelevant.
[153] Equal to 55%.
[154] As the technology is in its early phase, minor variances in the variables affecting the innovation may bring to long diffusion delays, or to earlier adoption.
[155] Depending on when the market matures and sales growth diminishes.

success of a new EV release[156] which would threaten incumbents' market share, or the realization that international Government's threat of enforcing and tightening penalties is real and potential losses high.

2.5.3 Fundamental variables under more detail

2.5.3.1 The dealer problem

Although there are many reasons why people might not be purchasing EVs at present, such as high prices, lack of model choices, range anxiety, recharging time, all these demand related problems are being gradually dealt with as time passes and technology improves. However, at present, one big alarming obstacle to EV diffusion can be found on the supply side and it is car dealers. This is because for a number of reasons they are reluctant to support the OEMs' "faint" push strategy with some "actively discouraging customers from going electric, talking up legacy ICE models"[157]

The reasons according to which dealers are reluctant at pushing EVs as vigorously as they usually do with ICE models are as follows:

1. Little knowledge. Even if salespersons do try to sell EVs, there is a general ignorance about the alternative powertrains' underlying technologies. This translates in misconceptions and misunderstandings when uneducated customers enter the dealership. The obvious consequence is poor customer service and the shift to the classic ICE models.

2. Business conflict of interest. Despite the EVs high selling price, they require much less maintenance and repair with respect to traditional ICE vehicles, greatly reducing the After-Sale revenues per car. This point is clearly expressed[158] by Tesla's founder Elon Musk, who is a clear supporter of the direct-sales business

[156] Such as the expected success of the Tesla model 3.
[157] Chargedevs.com
[158] "Existing franchise dealers have a fundamental conflict of interest between selling gasoline cars, which constitute the vast majority of their business, and selling the new technology of electric cars. It is impossible for them to explain the advantages of going electric without simultaneously undermining their traditional business. This would leave the electric car without a fair opportunity to make its case to an unfamiliar public" (Elon Musk).

model, in open conflict with the American NADA[159]. Dealer EV ignorance then, could be a clear excuse to refrain from selling future lower-maintenance vehicles.

3. Little to no sales organization standards. It was found[160] that most test-drives, a fundamental step[161] in the adoption decision process were conducted without fully-charged batteries and with salespersons clearly underestimating the vehicle's range and potential providing very misleading information[162]. All these details becoming a clear issue when referring to a decision with a high weight of purchase.

4. Poor model selection and sales effort. A final reason why EVs are poorly pushed by dealers is also related to the demand problem and OEM poor supply offer. As EV volumes are low, dealers have little incentives at following EV potential customers in the sales process, concentrating their efforts on higher volume models needed to reach the OEM sales targets[163] and reach profitability.

This is a big problem which could hamper EV diffusion and lengthen its time of adoption. In this situation, a clear correlation was observed between salespersons' knowledge about EVs and their recommendation of buying one, making a strong point for OEM's to create standardized instruction programs for their dealer networks.

2.5.3.2 Network externality effects in the automotive industry

The automotive industry is particularly affected by network externality effects. In the case of EVs there are many positive network externalities which would benefit product users but cannot be internalized by any specific private agent leading to market inefficiencies and slower diffusion. These can be summarized in direct and indirect externalities. The first mainly consistent in a reduced risk-aversion by the early majority after innovators and early adopters have made their acquisition and increased product choice once the technology reaches the mass diffusion phase. The latter mainly includes the increased value of the technology once the refueling and

[159] National Automobile Dealers Association.
[160] Always in Chargedevs.com
[161] Trialability, as explained by Rogers.
[162] A test by Consumer reports (CR) testing 85 dealerships found that only 19% of salespeople gave reasonably accurate answers to the questions posed.
[163] OEMs' set sales targets which reward the dealer once the objective is reached.

recharging infrastructure is in place and the battery efficiency has reached a higher maturity point. On the contrary supply side (pecuniary) externalities are created by the spillover effects in manufacturing and energy supply due to the learning curve effect and scale economies in production, whose value can only be extracted once the diffusion tipping point is reached[164]. The accumulation of these positive feedback externalities during the diffusion process create tipping points whose timing and necessary conditions are as of today highly uncertain due to the numerous affecting variables.[165]

Adding to the positive feedback effects, there are also some negative ones which should be of great concern. As more alternative powertrain vehicles are sold, the transition evolves from the innovator to the early majority phase, leaving that market segment not only partly saturated, but also difficult to further target as the technology loses its sense of novelty and the innovators' demand and willingness to pay a price premium diminishes. Under this reasoning, the technology's diffusion process will become harder after the innovator target becomes saturated as the easiest buyers have already been exploited. To further continue EV adoption, its advantages with respect to current technologies will have to become more and more compelling in order to capture additional users. This seems in countertrend with what has been expressed up to now, and thus should be deeply examined by automakers while formulating an entry strategy.

Connected to the network externality problems is the automaker's dilemma in which an increased availability of EVs "provides a dilemma for automakers as they sacrifice traditional cash-cow internal combustion engine sales for expensive and lower-margin electric cars, necessary to meet onerous new emissions legislation"[166] creating big pressure on which decisions to take and when to execute them.

[164] Greene et al. (2014).
[165] Always Greene et al. (2014).
[166] M. Dean, Bloomberg 2017.

2.5.3.3 The chicken or egg infrastructure problem

The EV-charging infrastructure relationship represents a clear example of a network externality problem in which two systems depend on each other to grow and generate a market failure. This is due to the fact that EV charging stations require big amounts of capital whose repayment is directly proportional to the number of EVs in the area. At the same time though, the number of EVs in the area will highly depend on the available charging infrastructure[167], as demand is strictly dependent on the refueling possibilities. This means that there are negative incentives for both to invest too early before the complement product has been developed. This can easily bring to a standstill, whose overcoming may only be achieved by two means. Either by government intervention, thanks to which investments can be made in one of the two systems creating a self-reinforcing mechanism which will then lead to the growth of both complementary markets, or by one of the two systems making a strong commitment in their products, creating enough incentives for the latter to invest on their project. At present in the EV market, both strategies are being pursued by public and private entities. As what regards the public spectrum, governments in some countries have been investing heavily in public recharging infrastructures in an attempt to foster EV demand and diffusion. A clear example of this deadlock overcoming attempt can be found in China’s heavy investments in a public fast-charging infrastructure[168] which falls within the broader Green Energy plan[169]. Governments have also promoted private investments in the charging network by granting public incentives. This has led to a stock of public charging points close to 188 thousand[170], and of private charging points close to 1,3 million in 2016[171]. As what regards the private spectrum instead, the system has to be divided between outside investors and automakers. This is because, if the first have no incentives in entering

[167] Early adopters were found to mostly have the opportunity of recharging at home or at work, for further demand expansion, public stations are required (McKinsey report 2014).
[168] With an announced 12 thousand public EV charging stations and infrastructures capable of handling 5 million EVs by 2020 (Bloomberg 2015).
[169] Which aims at shifting Energy production from coal to cleaner renewable sources. At present China has announced $361 billion investments into renewable power generation by 2020 (Reuters, 2017).
[170] Including 28 thousand fast charging stations.
[171] Almost double with respect to 2015, EM report 2016.

the market too early[172] and will underinvest until the EV market expands, greatly increasing diffusion time, the latter have a direct interest in having the two systems grow together. The problem arises when one automaker's investment in providing users refueling stations might spillover to freeriding rivals, leading to a general cut back on complementary asset investments[173]. Even though this solution harms all automakers by decreasing the total combined value of EVs to users, investing solely represents an unacceptable financial risk for most automakers.

A solution to this problem has been found by creating automotive partnerships for public charging infrastructures. A clear example are the Nissan-Renault[174] and the BMW-Daimler-Ford-Volkswagen groups' Joint Ventures[175], with the latter signed in 2016 to deploy a fast-charging network throughout Europe in an attempt to foster EV demand in the world's second largest economy[176]. The JV is also a pursuit to create a standard for fast charging technologies in order to secure long-distance travel for all EVs throughout Europe.

As of today, there is a clear charging infrastructure shortage in many countries[177], especially in the fast-charging options which are indispensable for intercity travel[178], which however is being addressed effectively through the cited public and private investments, with the sector showing an 81% increase from 2016 to 2017, higher than that registered for the EV market[179].

2.5.3.4 Battery cost & performance and TCO[180]

As of today, the TCO gap between ICE and EV of comparable models[181] ranges from €5000 to €20000[182] with the lion's share of the price imbalance accruing to current

[172] A clear example could be Better Place's bankruptcy in 2013.
[173] Li J. (2017).
[174] Other alliances have been formed, an example is the Japanese alliance: Toyota-Honda-Mitsubishi-Nissan to create a Japanese national charging network (Nippon Charging Network). Source: EVobsession.com
[175] Source: media.daimler.com
[176] Worth $19,2 trillion.
[177] The network equilibrium is below the established reference value of 1 in most countries.
[178] Slow charging may take multiple hours to reach an 80% battery charge, making intercity travel impossible for EVs. Fast charging on the other hand requires 20-30 minutes depending on battery size and charging speed.
[179] Showing a 53% growth rate in 2016.
[180] Total cost of ownership

battery prices. As already examined, the current gap may only be bridged by government incentives, consumer willingness to pay a price premium or both. This situation is destined to improve as economies of scale build up, technology advances, supply chain matures and battery cost diminishes. This will also bring to battery yield improvements which are much needed at present to increase travel range and charging time. According to a McKinsey 2017 report, supported by BNEF's findings, battery pack costs have fallen from a $1000 to $227 per kWh in the 2010-2016 period representing a 77% decrease. Furthermore, as seen in Figure 13, batteries are expected to keep declining through 2030 below the $100 figure reversing the TCO price gap with ICE vehicles, with Li-Ion battery's share of car value falling from the current 40% to an estimated 20%.

Despite the promising future development of battery packs, the present competitiveness of cheaper ICE models translates in a lack of profitability for EVs for the next two or three product cycles[183]. In this scenario, automakers capable of acquiring battery packs at a lower cost[184] will find themselves ahead of competition and earning higher margins. Moreover, better than forecasted battery pack improvements could greatly anticipate the profitability scenario. A clear example could be Tesla's announced 35% battery cost reduction for the upcoming model 3[185], which would bring the battery pack cost down from to $124/kWh against the currently stated $190. It is worthy of notice how some energy experts[186] set the EV TCO superiority once battery packs reach the $100/kWh.

However bright might the future of battery packs seem, the dependence of technology and performance improvements on a great multitude of factors, including material scarcity and technological limitation or technology S-curves[187], creates an uncertainty

[181] For an annual mileage of 20,000 km and a 4 year holding period as calculated by the McKinsey report 2014.
[182] Or €7000 according to the 2016 EMR for a 10-year life span medium sized vehicle.
[183] Or between 2025-2030 as reported by McKinsey 2016.
[184] Either by vertically integrating OEM battery producers, or by signing partnerships or JVs with specialized battery producers such as Samsung and LG.
[185] Reached thanks to a forecasted battery mass production in the Reno Gigafactory.
[186] Including Tony Seba, Stanford University instructor and EV author.
[187] Li-ion technology has made great progress since 2010 and could reach maturity in the next decade.

over its future battery density growth and production cost decrease, making the actual projections best-estimates at most[188].

As what regards investment strategies, automakers should also consider how electric TCO highly depends on car size and use creating differing scenarios for large and small vehicles or passenger and commercial vehicles. In this context, segmentation strategies considering the differing TCO can be applied. In this context, automaker future powertrain portfolios would vary also considering the different market use and size of the vehicles. This creates strong incentives for powertrain differentiation, based on each technology's characteristics and advantages, with BEVs dominating the small car shorter range market and FCEVs dominating the large car, longer range market.

In this context, automakers choosing a segmentation strategy should thus predict what the dominant market for EVs will be and invest in the powertrain which better fits that market.

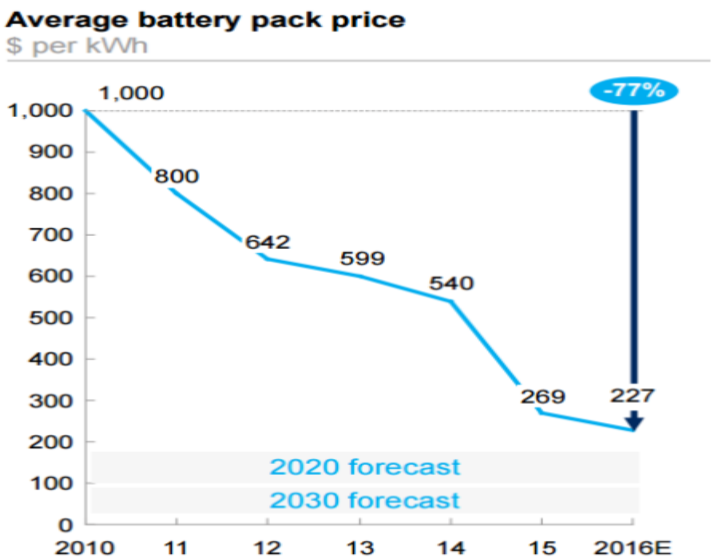

Figure 13, Source: McKinsey report 2017.

[188] Which have currently increase at 5% and decreased at 8% per year. Gonzalez F. 2016.

2.6 EV market entry strategies

2.6.1 Scope of investments for the 2017-2021 period.

For the period 2017-2021, automakers are following differing investment entry strategies. When deciding what their future powertrain portfolio will look like, they need to decide a) in how many segments they will compete in and b) how many products they will introduce in each segment[189]. By defining a low and a high value for each segments a 2 by 2 matrix is created as depicted in figure 14.

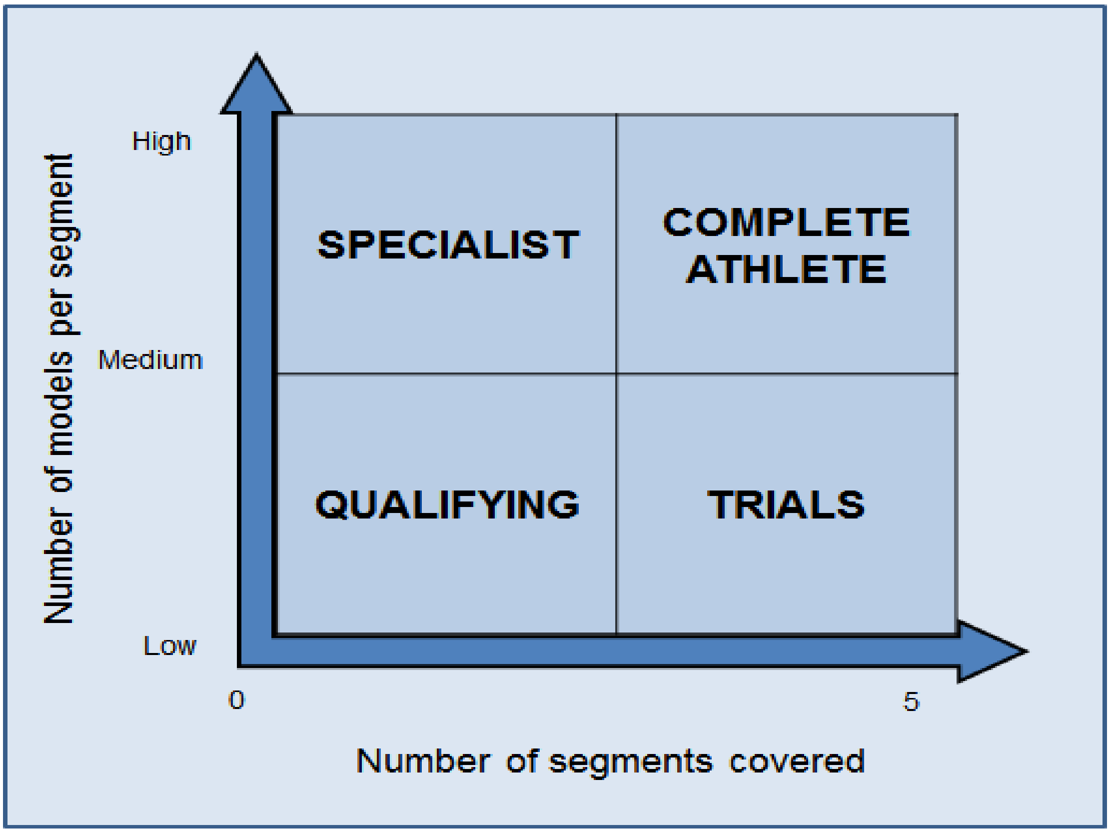

Figure 14, EV investment strategies for the period 2017-2021.

According to figure 14, we can divide EV automakers in specialists, qualifying, trials and complete athletes depending on the covered segments and the models per segment.

Specialists will introduce a focused and specialized market portfolio aimed at covering a few segments with a wide range of models. The strategy is that of becoming market leaders in those few segments which the automakers believe has the greatest market

[189] As suggested by Chiesa et al. (2017), EM report.

diffusion potential. By introducing multiple models, market share is increased resulting in higher sales volumes for that given product structure. This is fundamental for creating a relative advantage by riding the learning curve ahead of rivals and creating volume entry barriers[190]. This strategy can be particularly successful if the market predictions are correct and a few firms manage to monopolize the biggest car segment, or for smaller players to monopolize niche markets. However, as its success is based on the concentration of investments on the segment predicted to be of central importance for the new powertrain alternative, it is also the riskiest strategy at present.

Qualifying will invest on a very limited portfolio, covering a few segments with a few products. This is typical of market skeptics who believe the risk of investing is still too high. It is also common among firms which desire to postpone large investments in the hope of free-riding on competitors' errors and market education expenses or due to the impossibility of being early entrants because of the lack of necessary capabilities and knowledge at present.

Trials will aim at offering a few models (one or two) in every market segment which they plan to compete in. This diversification strategy follows an opposite cost-benefit analysis with respect to the specialist one. This is because it aims at reducing the investment risk by not focusing all investment on one segment, but at the same time reduces the market penetration potential and the related learning curve and production benefits. However, even though the scale effect is reduced, the multiplicity of covered segments gives automakers the possibility to be fast entrants in the segment which demonstrates to better respond to the new powertrains. This is particularly relevant in the EV context, since at present efficient[191] Li-Ion[192] battery packs are very expensive and would create great relative price imbalances especially in the smaller car segments. Concentrating all investments in this segment and pursuing a wrong entry strategy and marketing proposal[193] could entail large losses on funds

[190] Such as lower production costs and higher performance.
[191] Which will be defined as a long driving range EPA potential of 350 km.
[192] Lithium-ion cells
[193] As will be explained in chapter X, for small car segments such as A&B, new business models, or alternative mobility strategies could be pursued. The long-range segment C 60kWh Chevy Volt battery

invested. Moreover, being present in all product segments give higher visibility to the firm's innovative efforts and create a stronger branding effect.

Complete athletes represent automakers who plan to offer a mature alternative powertrain portfolio covering multiple segments with a wide range of models. This strategy of total commitment is at present very difficult to sustain since it implies huge investments and a sudden shift from the old to a renewed portfolio with all the connected consequences.[194] If incumbents could be reluctant to commit themselves so heavily due to demand and profit related issues[195], new entrants also would have a difficult time following such a strategy due to the limited capital available with respect to the necessary required investments.

2.6.2 Early entrants, early followers and laggards.

The automotive industry is well known for having lower than average margins primarily because of intense competition. The competitive rivalry makes it difficult for firms to pass upstream price increases down the value chain to final customers making it difficult to maintain high margins. Operating profitability is commonly measured by the EBITDA[196] margin which varies significantly between automakers[197] and averages at 8%[198]. Being that the automotive industry is technology-intensive, mass production is key in order to reach profitability for most car models[199]. In this context automakers might find it counterproductive to invest and push EVs which have a present low sales volume potential and which according to most automakers, sell at a cost[200] substituting their current ICE models. However, future compliance to emission

pack with a 2016 stated cost of $145 per kWh (an optimistic cost, most manufacturers state higher battery prices) would have a production cost of almost $9000, a significant purchase cost differential when compared to a similar ICE car.

[194] Business models could change, customers and dealers should be educated with the risk of losing business in the short-term etc.

[195] Uncertainty of demand, and lower profit margins of EV with respect to ICE engines at least in the short-term.

[196] Earnings before interest, tax, depreciation and amortization.

[197] On the high-end, Toyota and Honda motors reach 13,8 and 13,1% respectively, due to a favorable weak Yen and high exports.

[198] Source: market realist.com

[199] Every-day average car models need to reach high volumes to recoup investments due to their low margins. A different story can be made for the luxury segment, in which higher margins permit lower production volumes.

[200] An EV Nissan leaf aggressively priced at €30 thousand not only sells at no-or-negative margin but still represents a high price differential when compared to its ICE counterpart.

standards and required efficiency investments could also represent a cost for most automakers. Which cost is higher will influence the choice for most companies who fear their margins will further decrease[201].

In this environment, specific strategies will be pursued regarding timing of entry. Always Wesseling et al. (2015), show how responding to an external incentive such as the ZEV mandate[202], firms influenced by the mandate “developed a stronger opportunity to innovate,[…],showing a significant difference in terms of asset position[203] during the R&D period”. Moreover, it was found that, following these initial developments, “large car manufacturers that have a stronger incentive and opportunity to innovate, will have marketed more EVs than their competitors during the early EV commercialization stage”. Confirming the cost-benefit reasoning stated above, and the incentives to maintain the incumbent inertia explained previously, timing of entry was found to be greatly influenced by the company’s current profitability situation, and its market penetration opportunity.

More precisely, data shows how a significant difference can be found in the EV sales volume between firms with an above average EV asset position and below average net income, and companies representing the opposite situation. So, as suggested by this correlation, established firms will be more inclined to follow a first mover EV mass market strategy when they have both the financial incentive (or on the contrary, when they do not face such a high profit margin gap between ICE and EV models), and opportunity, i.e. they display a high asset position and have a strong base for mass marketing as first-movers.[204] Automakers with some opportunity and average incentives have the potential to act as early followers. They have the incentives to market EVs but given their limited opportunity will have to do so after first-movers introduce their models. Moreover, given their lower asset specificity they have the potential to experiment more on powertrain alternatives. Late followers are

[201] Unless an industry common increase in prices will occur.
[202] A Californian law requiring automakers to sell a minimum amount of EVs proportional to the ICE models sold.
[203] Defined in terms of firms’ asset positions, relative to the value and amount of patent applications, partnerships, and prototypes.
[204] It was found however, by Wesseling et al. (2015), that displaying one of the two characteristics was not sufficient to move as an early entrant.

represented by companies with low incentives and high opportunity. This is because they initially have no incentive to innovate their product portfolio and prefer maintaining their old profitable business model. However, as soon as the EV market develops, and the menace of entry-barriers to late entrance increase, their high cash and asset position availability allow them to quickly respond and enter the market aggressively. Laggards instead will be characterized by low opportunity and a high cash margin availability (which currently translates in a low incentive to innovate). This situation follows the reasoning that even though at present these automakers have no incentive to innovate, nor do they have the opportunity, they do have the cash capacity to heavily invest when the situation evolves. However due to a slow time of reaction to these new powertrains they will be unable to reach the market in time. The last group will be formed by high incentive, i.e. low net income, low opportunity automakers. Also this group represents laggards[205] or late entrants, who not only do not dispose of the EV technological assets necessary to enter the market, but also do not have the funds required to heavily invest on the innovation and enter the market aggressively. Moreover, the current low earnings represent a further obstacle for their EV introduction, since they may be unwilling to compensate the potential loss per vehicle on EV sales. Also, pursuing the wrong entry strategy entails a higher risk for this group due to their lower margin for error. This group will represent the most diverse cluster as what regards strategy, with some automakers being also unwilling to invest either due to skepticism about the new powertrains' importance[206], interest in investing in another technology, or belief of the unprofitability of the investment opportunity.

Although automaker's strategy could be explained using the former classification[207], these can easily modify their competitive position by forming alliances or collaborative strategies. These can represent a quick and efficient way to obtain or consolidate one's

[205] With the due exceptions
[206] FCA was not interested in EV technology until 2016, when it announced it will follow also this technology. Marchionne earlier stated he did not share the same certainty that other automakers had about the BEV as the future of mobility. He did not believe batteries could improve so quickly and stressed how he believed Hydrogen would represent the real future dominating technology for EVs.
[207] Wesseling adapts the model to actual data using a Mann-Whitney test.

asset position. First-movers can create partnerships to mass market EVs[208] and build strong volume entry barriers. Laggards can temporarily form collaborations with first-movers and market EVs by selling the latter's ready-made EVs under their brand[209] etc. Hence, adding to the decision whether to when to develop technologies and enter the market, a further decision of whether to develop assets internally or access to them externally must also be taken into consideration.

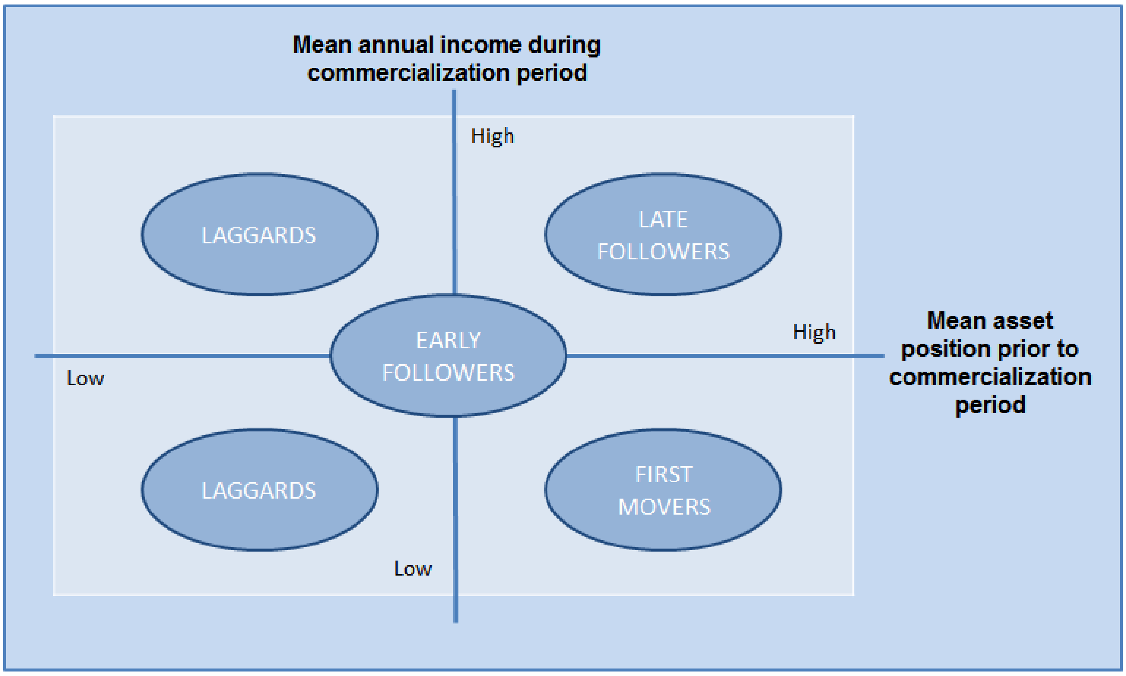

Figure 15, Timing of entry of established competitors based upon EV asset and annual income position prior to commercialization period. The figure is an extension of the study by Wesseling et al. (2015) regarding automaker incentives to invest in alternative powertrains.

Strategizing, in this context, by possessing the highest asset position from the start, first-movers possess a technological competitive advantage and should try to diversify from the start, with the possibility of profiting from the trade or licensing of their technologies at later stages. On the contrary, laggards who lack the necessary financial availability and do not possess a sufficient asset position should refrain from diversifying. This is due to the risk brought by diversification in this stage, where

[208] Renault-Nissan alliance.
[209] PSA-Mitsubishi collaboration.

technological development is expensive and first-movers have already created sufficient entry barriers. Effort concentration and niche market targeting are preferable in this case.

2.6.3 Capacity based innovation strategies

According to Trott (2005) and other studies relating to innovation strategy[210] companies may follow a wide range of different innovation strategies depending on their resources, capabilities, knowledge and future vision. Out of these studies, four have been more widely studied and could be depicted on a two-by-two matrix depending on the R&D effort displayed and the intrinsic manufacturing capacity possessed by the firms. Other variables affect the strategic decisions, such as the marketing effort and capacity, which is critical for first-movers and early followers. However, the former variables can be defined as determinant for the pursuance of each and every market approach. The strategies displayed in Figure 16 can be defined as:

1. Leader or offensive strategy, which aims launching the product to market before of competition. This strategy requires the highest R&D investments as not only does the firm have to develop the technology fully, it also has to create market awareness and customer education, implying very high R&D and marketing costs. Given the amount of risk involved, companies pursuing this strategy usually are characterized by a strong corporate commitment to innovation and risk.[211]

2. Fast-follower or defensive strategy, which aims at responding quickly to first-movers after they have entered and invested in marketing the technology. Necessary for such a strategy is the firm's marketing agility in both manufacturing, re-designing and commercializing the product such as to be quick enough to follow the first-movers. A substantial technology base obtained through prior technology R&D spending is necessary to introduce better versions of the product with the aim of stealing the first-mover's market share. In this context, a strong absorptive

[210] Porter 1980, Tidd et al. 2005.
[211] A clear example could be Tesla's all in strategy on EV powertrain technology and market diffusion connected to the figure of Elon Musk.

capacity and lean manufacturing process can make the difference in introducing better performing, lower cost products.

3. Cost minimizer or imitative strategy, aiming at producing the given technology at the lowest cost possible. In order to pursue such a strategy exceptional production skills and a strong process and product engineering capability must be in place. These large scale producers usually do not possess prior technology asset knowledge and do not wish to invest much on it. Contrarily they will often purchase it or license it externally concentrating all efforts on process improvements and low cost production.

4. Market segmentation strategy, aiming at eluding competition and concentrating all marketing and production efforts in the attempt of satisfying a particular market segment or niche. In this niche, mass production is of less importance and customers are less price sensitive and more respondent to product differentiation, giving the possibility to later more focused entrants to compete.

However, it is important to notice how in the real world, the competitive environment is dynamic, and strategies can evolve over time. Early followers can find themselves missing the necessary production capacities and opt for a niche strategy, or contrarily, niche manufacturers can scale up production and pass to the mass market[212]. In particular, a study by Khalebadabi (2008) shows how many EV pioneers started commercializing EVs by following a hybrid strategy. They followed both a leader strategy by investing large amounts in R&D and marketing effort[213] and a market segmentation strategy by firstly targeting small niche markets and then expanding to the larger mass market[214]. In this context market niches were found to be supportive of both radical and incremental innovations.

[212] This last strategy is particularly relevant to the automotive industry and is being largely used in for the introduction of EVs.
[213] The Japanese trio Toyota, Honda and Nissan are also well known for pursuing a long term Green CRM strategy, also confirming the hypothesis regarding the need of a strong corporate vision to be a market leader.
[214] Which however is still very limited.

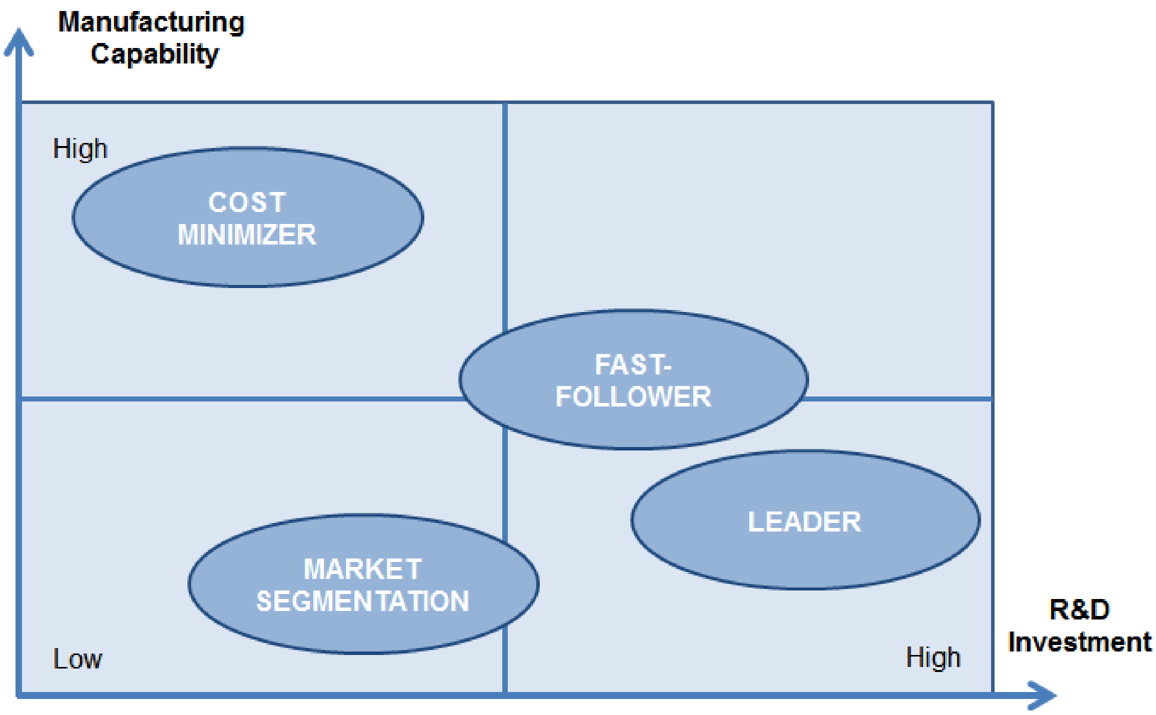

Figure 16. Reinterpretation of the fundamental variables affecting the strategic decision of innovation strategies following Trott (2005) and others studies on Innovation strategy.

2.6.4 New market entrant strategies

Since the mid-2000s many companies have entered the automotive sector by investing solely, or relying heavily on the EV powertrains. These can be divided in pure startups, and vertically integrating large component manufacturers.

The first group of entrants represent a wide range of actual or would-be automakers whose strategy is best described by Tesla's master plan: create a low volume expensive car, whose revenues can be used to create a larger volume, less expensive car and so on.[215] This is mainly due to the high upfront investments needed to mass produce vehicles and due to the fact that at present battery pack cost is not competitive and high price tag cars are needed to cover the price gap. This entails a

[215] Tesla's master plan as described by E. Musk: "The first master plan that I wrote 10 years ago is now in the final stages of completion. It wasn't all that complicated and basically consisted of: 1) Create a low volume car, which would necessarily be expensive 2) Use that money to develop a medium volume car at a lower price 3) Use that money to create an affordable, high volume car 4) AndProvide solar power. No kidding, this has literally been on our website for 10 years."

segmentation strategy will be mostly followed by any startup entrant, as it misses the necessary qualities needed to follow any other strategy. Such a low volume production is also due to the limited capitalization of most startups, since funds are difficult to achieve given the low success rate of car company startups[216]. Given low volume, economies of scale cannot be achieved, and targeting the high-end sports car segment seems to be a common strategy for most startups. In the pre-production and pre-commercialization phases, vaporware is very common among these players, especially when combined with pre-order payments, which enable to collect the much needed cash during the pre-production period. This practice also underlines the fragility of most EV startups during this initial phase, which runs the risk of becoming an economic bubble, with many companies on the brink of failure.[217]

The second group of entrants represent the most classical threat of new entry in a stable industry, where large component manufacturers invest in R&D or acquire an established company and downward vertically integrate their value chain. The reasons may be many, such as the opportunity to exploit a profitable situation or protected market, as happened with the surge of Chinese car manufacturers in the last decades. Or on a minor scale, and more belonging to the EV experience, would be the case of specialty technology producers such as those creating superior performing battery packs, or IT technological giants, who wish to diversify their business and start an EV venture usually on a small scale.[218] Also in this case, for new startups a segmentation strategy will be the one mostly followed with the aim of scaling up production once sales take off. On the other hand, diversifying big component manufacturers[219] who follow an acquisition strategy can more easily follow the incumbents' strategies,

[216] As of today, as stated by E.Musk, the number of American car companies which never went bankrupt is equal to two: Ford & Tesla. The latter however received $4,9 billion in Government funding according to data compiled by The Times (J.Hirsch L.A. Times, 2015).
[217] China's EV industry, with as many as 200 players is doomed to a massive shake-out as the central Government aims at imposing stricter technology standards with the aim of strengthening the bigger manufacturers and avoiding the tech bubble by limiting the number of permits for EV startups to 10. Source: Bloomberg technology 2016.
[218] A clear example could be Lucid Motors, an EV battery pack producer, venture in the EV supercar segment, whose release is expected in 2018 (Lucidmotors.com).
[219] A clear example could be represented by BYD, which after becoming the largest Chinese rechargeable battery manufacturer, acquired Tsinchuan Automobile Co Ltd, becoming a de facto large scale car manufacturer.

especially if possessing a monopolistic position in their market due to other than competitive factors[220].

[220] i.e. Regulatory, such as the regulation requesting a 50/50 JV for foreign car companies wishing to produce in mainland China.

3 Testing the Established Automakers' Electrification Commitment and Defining Entry Strategies for Different Players in the Market.

3.0 Methodology

In the following paragraphs a study will be conducted on established automakers' actual and projected investments based on publicly available data and reports. The automaker commitment analysis will be supported by reports by independent analysts relating to the future prospects of their EV strategies based on their current situation and their future developments. An independent analysis will be made for Tesla due to the exceptionality of its story and its predictable total commitment to electric vehicles. Also, Tesla will be introduced for first in such a way to set a unique benchmark for would-be EV players who wish to follow the different path.

Following the present and future situation which will result from the case by case analysis which will cover most of the established automakers, a consolidated analysis will be made following the three main entry strategies covered in Chapter 2. The analysis will look at the aggregate level of automakers' past, current and expected future technological levels, their incentives to commercialize EVs, their potential to do so in a cost-minimizing, profit-maximizing manner, the credibility of their commitments in such a manner to define what will possibly be the future evolution of the EV market by 2021. Market attractiveness will also be taken into consideration via its effect on the entry strategy decision. A situational analysis will also be used by considering how past events have influenced the evolutionary path of OEM's innovation strategy deviating it from the set corporate strategy.

After having defined what the possible development of the market in 2021 could look like, brief comments will be made on the use of alliances and collaborations in automaker innovation strategies, on the development of the hydrogen fuel-cell situation, which will not be decisive in the 2017-2021 period and on the spillover benefits of investments in EVs in alternative fields such as motorsports and the military.

Final remarks will be made on the need for both a clean energy chain in production and distribution, and for a wider international sustainability vision, which not only covers passenger vehicles, but also a wider variety of transportation means.

The latest developments in the EV market, which might alter the present analysis, and the future diffusion of alternative powertrains are contained in paragraph 3.10.

3.1 The Tesla experience

Tesla motors is a major American manufacturer of renewable assets including EVs, solar panels and Li-ion energy storage units. As of today, it represents the only EV[221] startup to have reached worldwide success and a market capitalization in line with that of the big automakers.[222]

Even though consumer needs and government regulations are really changing towards a more environmentally friendly mentality, most of merits of the mainstream acceptance and excitement which currently linger around EVs has to be attributed to Tesla's successful execution of its disruptive mission[223].

Differently from what most established auto makers had tried to do[224], Tesla did not point to the mass market directly, but instead tried to make EV compelling cars. It focused on making its cars not just simple substitutes of ICE vehicles, but exclusive "cool" cars which would have nothing to envy to their polluting "cousins". This was mainly done by demonstrating that electric cars can be sporty and fast, contrary to the

[221] It must be noticed that since 2003, no other car automaker startup ICE or alternative fuel engine has managed to reach Tesla's success, with a current market value close to that of the other American auto giants.
[222] Obviously Tesla's market capitalization depends on the current projections of its future performance, which are expected to be very bright, given the fact it has not made profits yet.
[223] "to accelerate the advent of sustainable transport by bringing compelling mass market electric cars to market as soon as possible" in such a way to become a "catalyst to accelerate the day of electric vehicles" (Teslamotors.com).
[224] Trying to build a relatively affordable car for the mass market.

common vision of them being slow as golf carts.[225] So this strategy stemmed from two reasons, the need to build an expensive car due to no economies of scale and high cost of production, and the need to change driver's vision about what potential EVs actually have.

After the first model was released and the hype around it build a strong brand image for the company, Tesla started its step by step strategy[226], increasing available models and product volumes and slowly lowering prices by simultaneously refining its technologies. At this point a different business model with respect to all established OEMs was defined, which was based on three points:

1. A direct sales distribution channel, which cut out big car dealerships. This was needed to eliminate the dealerships conflict of interest problem, increase sales profit margins and most importantly and most importantly increase the customer buyer experience through experienced sellers and unique showrooms[227].

2. High-grade car service, with unique car "Service Plus" locations and squads of mobile technicians who serve vehicles at client's homes.

3. A proprietary Supercharging network which enables Tesla drivers to charge at ultra-high speed[228] and which has been created ahead of competition.

As of today, this business model is unique for the automotive segment, but will be probably followed by most EV startups, which lack the power to bargain and the volumes deal with national dealerships. Direct sales to final customers will thus likely become a more common distribution mean in the evolving industry. This peculiarity of Tesla's total control over its sales and services is what made its stock price soar as if

[225] As happened with the Tesla roadster, the first EV sports car mass success. Business insider 2016.

[226] Emulating the typical technological-product lifecycle strategy which start by initially targeting affluent buyers with expensive high-end products, while waiting for public acceptance to diffuse. Moreover, as stated by Musk: "New technology in any field takes a few versions to optimize before reaching the mass market, and in this case it is competing with 150 years and trillions of dollars spent on gasoline cars", underlining its proximity to the technological-product life-cycle.

[227] Following the example of the unique value added that Apple stores bring to the Apple experience and products.

[228] The service is free for all cars bought before January 2017 (including all pre-orders), whereas for all next orders, after a certain free mileage, recharging will come at a cost. It is anyway a big value added for Tesla buyers.

production should indeed hit the mass market, profit margins would be more than double those of the established industry players.

Initiating the EV revolution, which sees almost all automakers announcing a full EV release in the next five years was Tesla's decision to go open source and release all patents[229] to producers for use in "good faith"[230]. Even though the reason for such a bold decision was stated to be that of accelerating the diffusion of EVs to better address the carbon crisis[231], a more profound reason could be found in the company financials. Tesla has invested huge amounts of capital in the EV technology and points at becoming a key player in this market. Its same future thus depends on the diffusion of EVs and their complementary assets. It is worthy of notice how the company still needs to report its first positive net profit. Under this perspective, Tesla's choice could then be interpreted as a move aimed at anticipating the expansion of the EV total market[232], preparing it for its mass volume product, the model 3 on which it placed its biggest bets.

Innovative has also been Tesla's decision to partner with Panasonic to invest in its Reno Gigafactory 1, setting what will become a standard for most automakers wishing to compete in the EV market, given their profitability dependence on the expensive battery packs. This step could also represent a first move towards a possible unification of the automotive value chain for the highest value added components down to end-users for the company under consideration. In fact, as found by Goldman Sachs in 2016, Tesla's degree of vertical integration had reached almost 80%, quite the opposite with what the industry standard is[233].

To further highlight its difference with respect to incumbents, the company has also planned to build its car with the enabling hard-ware to make them fully self-driving within the next year. With this vision, E. Musk stated how future Tesla buyers could actually repay their purchase expense by adding your car to the income-generating

[229] While keeping its trademarks and trade secrets in such a way to prevent the direct copying of its products.
[230] Forbes.com (2014).
[231] E. Musk: "It is impossible for Tesla to build electric cars fast enough to address the carbon crisis"
[232] As described in Forbe's article, it could be a way to encourage other companies at investing on the "charging stations and other products that would support Tesla's growth".
[233] Source: electrek.com (2016).

Tesla shared fleet while not in use, transforming what has been up to now considered an expense, into an investment.[234]

All these characteristics make Tesla a precursor of what the future EV automaker industry could look like, giving it a clear first mover competitive advantage in the evolving future market.

3.2 OEM automaker commitment analysis

Based on a 2016 article[235] by Brad Berman[236], established automaker EV effort credibility can be based on a series of measures and commitment assessments based on a series of factors.

The factors studied by Berman relating to OEMs' EV commitment are the following: a) Ground up design, indicating the amount of investments made on designing specific powertrains for EVs, b) Size of production run, indicating the amount of EVs being currently sold, in such a manner to distinguish between EV marketing and real EV effort[237], c) Geographical scope and vehicle affordability, which directly relate to the former factor as they influence the production volume, d) Range of vehicles, where a single release may indicate low EV efforts and commitment and lastly e) Comments from leadership, which most clearly represent the company's current vision & mood relative to its future EV commitment[238].

[234] As found in Master Plan Part Deux, E. Musk states: "You will also be able to add your car to the Tesla shared fleet just by tapping a button on the Tesla phone app and have it generate income for you while you're at work or on vacation, significantly offsetting and at times potentially exceeding the monthly loan or lease cost. This dramatically lowers the true cost of ownership to the point where almost anyone could own a Tesla. Since most cars are only in use by their owner for 5% to 10% of the day, the fundamental economic utility of a true self-driving car is likely to be several times that of a car which is not.

[235] Source: plugincars.com

[236] A leading writer and researcher for EV and green transportation.

[237] Where the first simply relates to releasing an EV model without backing it with serious commitments, while the latter implies a serious product release with all the relating expenses and volumes sold.

[238] CEO comments regarding EVs as being "non-sense" , unprofitable or technologically unviable, strongly undermine the company's credibility regarding its EV current and future efforts.

Adding to the previous, another report by CLSA[239] ranks the major OEM auto manufacturers' EV position based on the strength, future prospects and credibility of their EV commitment, as independently evaluated by CLSA analysts.

These two studies will hence be used to integrate the analysis regarding the incumbent and the new entrants EV market strategy for the next few years[240], based on the inquiry made in chapters 1 & 2, and on the publicly available data regarding the automakers' future commitments.[241]

To make the analysis as clear as possible, the automakers will be briefly studied both individually and at an aggregate level, in such a way to make it possible to define the presence of any trends regarding to current alternative powertrain investment strategies. This will highlight automakers strategies after taking into consideration what their current beliefs are regarding the next 10 years of powertrain mobility, whether EVs will rise and dominate the market, or ICEs will maintain their market share intact.

3.2.1 BMW Group

The BMW Group started testing the EV market back in 2008, when it released a limited production electric Mini Cooper. Since then it developed a more integrated and sophisticated EV strategy, investing heavily in alternative powertrains with the aim of developing an extensive EV portfolio, by adapting each technology to its best use. Thanks to this strategy and its Efficient Dynamics plan, it is not only investing in improving the whole powertrain efficiency ratios, but also in developing both a BEV and a FC powertrain (in collaboration with Toyota, due to the high investment risks involved)[242], in order to have the possibility to build both long range, fast recharging

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[239] An autonomous industry analysis firm (www.clsa.com/special/autocalypse/) which highlights the largest automakers by market cap and ranks each with a score out of 4 for its positioning in the EV industry, as a benchmark, Tesla's commitment to a 100% electrified powertrain is given a score of 4, representing the industry disruptor with no legacy issues.

[240] Mostly up to 2020, arriving until 2022, due to the decreasing reliability of future commitments as they are postponed in time.

[241] Varying from company statements, to industry analysis and established consultancy reports.

[242] "The BMW Group is conducting intensive R&D in the area of fuel cells and hydrogen tanks, with the aim of series-producing emission-free vehicles combining extensive range with short refueling times.

and shorter range longer recharging vehicles, depending on the evolution of the fundamental enabling technologies. More precisely, BMW is investing in FC EVs, with the prospect of adapting it to larger vehicles needed for driving longer distances, both passenger & commercial, under the prospect of the technology becoming mainstream.

However, in the period up to 2020 the main focus will be that of expanding the offering of plug-in versions of current ICE models (currently, Series 2,3,5,7 and X5), and introducing some BEV models (currently the i3 is the only one on the market).

Important is the commercialization of the appositely designed plug-in product line eDrive[243] comprised by the i-3 & i-8, which demonstrate BMWs serious efforts in the creation of an alternative powertrain portfolio complemented by innovative light-weight carbon-fiber components to increase range. Moreover, BMW is "doubling down in the electric car space by committing to at least two new electric vehicles by 2020", with a planned roll-out of a battery powered BMW X3 SUV and Mini Cooper,[244] confirming the need to rely on the SUV segment to recoup the high density electric battery costs.

To complement the analysis, CLSA gave a score of 3 out of 4, given i3's worldwide commercialization, i8's design & material innovativeness, and the expectation of having a full plug-in model portfolio by 2025.[245] This seems in line with a company that has prepared a clear EV strategy, even if EV sales volumes will remain relatively low for the period 2017-2020.

3.2.2 FCA Group

FCA seems to be the less sensitive to the alternative powertrain mission and development for a series of reasons. Firstly, as can be seen in Figure 4, the group scores particularly high in meeting the 2021 emission standards due to its current low

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The development of cars powered by fuel cells has received additional impetus from the research cooperation between the BMW Group and Toyota in this field." BMW corporate.

[243] With a stated electric motor energy efficiency of up to 96% (Business Insider 2016) & a perfect fit between performance and emission control.

[244] Source: Bloomberg.com

[245] Source: www.clsa.com/special/autocalypse

emission engines. Moreover, FCA has already incurred big investments in other alternative non-EV technologies and hence are pursuing a different sustainability path. In particular, FCA represents the market leader in methane[246] fuelled cars with a 2015 market share in Europe of almost 50%, equivalent to over 44 thousand vehicles sold[247]. Given 2016's agreement between FCA & Snam to increase the methane stations in certain countries it seems that FCA will continue betting on this alternative powertrain for the near future[248]. Adding to these considerations are Marchionne's announcements regarding the unprofitability of EVs[249]. His negative view on EV economics[250] is supported by the current absence of EVs in the conglomerate's portfolio[251] and the announcement that by 2020 there will be a limited release of plug-in models[252]. In fact, FCA's strategy will mostly be that of enlarging the use of methane and biomass fuel solution, improve powertrain efficiency and introduce hybrid[253] powertrain solutions, in such a way to efficiently reduce fuel consumption and compel with the restringing emission standards.[254]

But even though Marchionne previously stated how electric cars weren't the solution and were unprofitable to produce, maybe in an attempt to justify the company's differing position, he recently reconsidered his view[255] stating how Fiat can not only compete in the market, but even rival Tesla with the launch of a pure electric Maserati[256]. With some reservations[257] however, Marchionne did state how according

[246] A cleaner fuel with respect to petrol (23 times less CO2 emissions), and cheaper with respect to current EV offerings. It is also currently the most available gas in nature and can also be extracted from livestock discharge.
[247] Source:fcaspace.com
[248] EMR 2017.
[249]As stated in May 2014: "I hope you don't buy [the Fiat 500e] because every time I sell one it costs me $14,000."
[250] Which reflects a distrust on the electric powertrain solution both technologically and economically.
[251] The Fiat 500e is only sold in California, where regulations require the presence of at least one electric model on the market.
[252] Chrysler Pacifica plug-in release in 2017. No news of an upcoming mass market release for the 500e, but a small Fiat EV could be released in Europe by 2020.
[253] Both mild hybrids and plug-in hybrids where needed, to respond effectively to government regulations.
[254] Source: FCA corporate.
[255] Probably due to a changing environment which is giving a lot of importance to electric powertrains (the hype) against other alternative solutions, such as methane and biomass.
[256] As stated by Marchionne at Bloomberg in 2016: "I've always thought the economic model that supports Tesla is something that Fiat Chrysler could replicate as we have the brand and the vehicles to do it.". This statement was made with the announced released of the EV Maserati Alfieri in 2020.

to him, in 2021 most automakers will follow hybridizations as a mean to meet the stringent emission standards.

CLSA gave FCA a 1,5 score underlining how despite it is currently selling an EV version in California and Oregon[258], the company's statements and low transparency levels on current and future strategies[259] highly questions its EV commitment[260].

3.2.3 Daimler[261]

Daimler group started offering e-models back in 2009 with the release of its first Smart e-Drive. Despite the technical shortcomings and low sales[262] it maintained the model in its portfolio and expanded it by introducing the Mercedes B Class EV in 2014. His historical analysis represents a good start for Daimler, which however promises even more in the long term. Considering plug-in versions of current ICE models the group currently offers 10 vehicle choices[263]. Moreover, with the aim of being "the number one in the premium segment in terms of profitability and also in terms of unit sales" Daimler has set an integrated EV approach creating the EQ[264] brand which will complement the current ICE model versions by offering totally new exclusive EV models in such a way to propose a "comprehensive offering around electric mobility"[265]. This EQ portfolio will be based on a new separate powertrain platform which will be used to produce exclusively the different future full BEV models.[266]

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[257] "I'm not as convinced as some others are about the fact that electrification is the solution for all of man's ills," said Marchionne. "We need to experiment as we are doing now with connected cars and mobility as electrification is one of the potential answers."

[258] With sales averaging 163 a month (plugincars.com 2016).

[259] The sales figures for the 500e are not available to the public, but have been estimated at best.

[260] It is important to state how this does not mean FCA is not concerned about the environment, but only does not seem committed to the EV powertrain alternative. However a strong focus seems to be put on profitability putting FCA's sustainability efforts in a bad light to the general public.

[261] Mercedes & Smart.

[262] Source: plugincars.com 2016.

[263] "The plug-in product initiative at Mercedes-Benz is in full swing: Today, we already have eight plug-in hybrids in our product range, and by 2017 there will be ten." (Daimler Corporate). (GEN 3) hybrid powertrain releases started in 2016 and will continue up to 2020.

[264] Electric Quotient.

[265] With the goal of having up to 10 full BEV models on the market by 2022 (updated in May 2017 by Daimler's Chairman Zetsche) with the goal of its electrified sales representing 15-25% of its total sales.

[266] As stated by Daimler BoM member A. Kallenius: "With EQ, we're going a step further. Under this brand, we're bundling our entire know-how regarding intelligent electric mobility from Mercedes-Benz."

Confirming its stated commitment, $1 billion have been invested in improving its battery production network and its first exclusive EQ, an EV SUV, will be released by 2019.[267]

However, even though this strategy of using a separate platform and starting with the introduction of a high-end car to the market, seems to be similar to that of other automakers, Daimler differs in its intention to invest electric throughout the whole line, from small cars to large and heavy logistic trucks[268]. Moreover according to an interview to Daimler's head D. Zetsche, found in the Fortune (2017) article[269], the group has opted to step back from F-Cell EV development as "declining battery costs have made fuel cell vehicles uncompetitive with electric cars." Other underlining motives were the battery's increasing range potential and the ready in place recharging network, which would further undermine fuel cell potential since range was a major reason for its development, and the missing production and distribution hydrogen network is a strong disincentive to invest. Daimler is then currently investing heavily on EVs[270], while undermining F-Cell market applicability, moving closer to Tesla's and away from Toyota's view of the future of mobility.[271]

CLSA awarded Daimler' commitment with a 3 out of 4 score underlining its large plug-in offering and BEV presence as of 2017 and the large investments in the EQ brand portfolio starting with the 2019 release of a SUV model.

3.2.4 Ford

In April 2017, Ford's CEO announced the automaker would not be left behind in the development race of long range EVs. Backing this announcement is the company's $4,5 billion investment plan to develop 13 new electric vehicles, of which 7 within the next

[267] Further investments of $11 billion are expected to develop the EQ brand for the 2017-2025 period.
[268] With models: Urban eTruck, the Vision Van, and the FUSO eCanter pioneering in heavy duty electric mobility. This differs from other automakers who currently pursue the Fuel Cell electric option for larger automotive powertrains.
[269] Fortune.com (2017), by D. Morris.
[270] To recall: the BMW, Daimler, Ford, Volkswagen, Audi & Porsche JV for recharging stations' production.
[271] Daimler will however maintain a small development plan for Fuel Cell vehicles with the development of a GLC F-cell SUV in 2017.

four years[272]. The plan is part of a strategy aimed at putting Ford among the top competitors of the new mobility solutions industry, comprising electrified and autonomous vehicles. However, out of the 7 new releases which are mostly represented by hybrid and plug-in versions of ICE models, only one will be a pure BEV. Following current market trends[273] and the premium market segment entry strategy, the only new long-range BEV release will be an SUV. Complementing the current EV offering of a short range BEV, two plug-ins and a hybrid model[274], the new releases underline Ford's stronger belief in plug-in versions of current ICE models rather than full BEVs. Ford's EV strategy can thus be seen as a diversified hybridization strategy aiming at offering an electric solution for all of its most popular segments.[275] At present the strategy has not brought any single market success, however the combined sales of the automaker's plug-in models do exceed those of the Nissan Leaf & Chevy Volt hits in the US market[276]. Taking this into consideration, Ford results among the top competitors for the plug-in EV utility market. However, stronger efforts will be needed to put Ford in a leadership role for the long-range, large-battery pack EV segment.

Punishing this strong focus on hybridization CLSA assigned Ford a score of 2, underlining the importance to invest heavily in specific EV platforms in order to gain a leadership position in the future EV market. However, actual sales and high investment plans do strengthen its future EV commitment credibility.

3.2.5 GM Group

GM's commitment to transforming the mobility industry through a customer-centric electrification strategy can be found in its early market entry with the plug-in Chevrolet Volt back in December 2010. Despite the model always placed between the

[272] Source: media.Ford.com.
[273] The current boom of the SUV segment.
[274] Ford Focus BEV, Fusion Energi Plug-in, C-max Plug-in, Fusion Hybrid.
[275] As stated by Ford's CEO: "Our investments and expanding lineup reflect our view that global offerings of electrified vehicles will exceed gasoline-powered vehicles within the next 15 years", by "electrifying proportionately its most popular, high-volume commercial vehicles, trucks, SUVs and performance vehicles." (Ford media press), such as the F-150 pick-up, the Mustang sports-car and the Transit van.
[276] Combined 25 thousand sales vs. 24,8 thousand of the Volt and 14 thousand on the Leaf (Insideevs.com).

first three for number of sales in US, sales volumes actually did not ramp up in the following years. This partly negative outcome did not stop GM from developing a full BEV model, the Chevrolet Spark, which was a further failure. Having invested billions in powertrain electrification and consequently having a lot at stake, strong of its patent leadership in the US[277], GM released the first mass market long-range EV in 2017. This was mainly possible thanks to the rapid progress GM has made on its Li-ion battery technology. The absence of a competitor in the long range low price segment as of now, makes this vehicle central to the automakers electrification strategy. As of today, the electric portfolio is comprised of a full long range BEV[278], two plug-in vehicles and a hybrid car[279]. This strategy seems to be aiming at offering mass market car models in order to ramp up car volume and reduce battery expenses per car. It is worthy of notice how this strategy is quite the opposite of Tesla's by starting bottom up and not the contrary[280].

This analysis seems in line with GM's stated objective of putting 500 thousand vehicles on the road in US with some form of electrification by 2017. Similar objectives have been assigned for Europe & China[281] through the co-branded models of Opel/Vauxhall, who adopt Chevrolet's same powertrain to offer electrified efficient mobility solutions.

Similarly to other automakers, GM has been investing on Fuel Cell technologies in collaboration with Honda[282] with the purpose of releasing a commercially viable model when the technology matures. To further confirm GM's commitment are its huge

[277] We lead all companies in U.S. clean-energy patents granted since 2002, according to the Clean Energy Patent Growth Index. We've received more than 700 patents in fuel cell technologies since 2002, more than any other company, according to the Clean Energy Patent Growth Index. The Patent Board ranked us No. 1 innovator in its quarterly automotive and transportation industry scorecard 13 consecutive times from 2012 (GM corporate).

[278] The Chevrolet Bolt, which has a starting MSRP of $37,495 with a stated 238 miles EPA battery range.

[279] Accordingly, Chevrolet Volt, Cadillac CT6 PHV (whose sales are almost inexistent, and finally the Chevrolet Malibu.

[280] It must be noticed however, how the premium segment Cadillac PHV sales have been almost inexistent, underlining how maybe a failed attempt was actually made.

[281] Reduce average carbon emissions of U.S. fleet by 15% by 2016, Opel/Vauxhall fleet in Europe by 27% by 2020; and China fleet 28% by 2020 (GM corporate strategy).

[282] The companies are investing a total of $85 million in the JV in hopes of beginning production in 2020. As stated the mission was as follow: "This foundation of outstanding teamwork will now take us to the stage of joint mass production of a fuel cell system that will help each company create new value for our customers in fuel cell vehicles of the future." Combined efforts are also under place to work with the US government to increase the national Hydrogen fueling station system.

investments in battery production plants with the aim of building a competitive advantage in this evolving industry.

Confirming the above analysis, CLSA gave GM a score of 3.5 underlining how, even though its market attempts up to now have not been major successes as with Tesla, the Chevrolet Bolt can be considered the first so-called affordable long-range electric car, and a potential game changer, together with Tesla's model 3. Despite the lower model availability with respect to other automakers, GM's efforts in battery production in the hope of producing an EV mass market hit[283] give credit to its stated and actual commitments to the alternative powertrain development.

3.2.6 Honda

"We've transformed how we operate at every level. From design and manufacturing to transportation and sales, we're reducing our environmental impact in all areas of operation. And we're voluntarily working to further reduce our CO2 emissions by 50% by the year 2050 compared to a year 2000 baseline."[284]

This and other strong statements[285] underline Honda's firm belief in following a systematic "Green Path" strategy aiming at reducing not only the cars emission, but emissions and pollutions generated by the company's whole value chain. If this position seems to be more extremist than that taken by most of its competitors, when transferring it to the alternative powertrain topic, Honda does not pursue a globally uniform electrification strategy. On the contrary it seems to be more realist than many other car manufacturers by setting potentially low-end objectives as what regards future portfolio electric penetration.

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[283] Also considering GM's combined EV sales (with Bolt sales being hampered by low inventory availability) are at present close to Tesla's combined sales, even if margins are considerably lower.

[284] Honda Corporate.

[285] "When one thinks about what automakers can do to help the environment, the immediate thought may be "improve fuel efficiency" or "develop alternatives to gasoline." Both are important to reducing CO2 emissions that contribute to climate change. That's why we're developing zero emission vehicles and improved hybrid technology to meet the challenge of reducing CO2." "Designing, building, delivering, and selling a car also have environmental impacts that we are working to reduce or even eliminate. This holistic approach to reducing the impacts in all areas of our business is what we call "Green Path."

If back in 2011 Honda’s CEO stated both how EVs were only suited for small cars and not for the U.S. market[286] and how hybridization was the best solution for the 2025 period against plug-in and pure BEV models, it might be now feeling the electric pressure from the many competitors entering the market. This has brought a shift in strategy with the company now pursuing the release of a mix of BEV, plug-in and hybrid models by 2025. This however has to be confined to the European market, for which Honda’s Europe CEO Katsushi Inoue recently set the 2025 objective called Honda’s ‘Electric Vision’ consisting in two thirds of European sales to feature electrified powertrains by 2025.[287]

The main reason for Honda’s low BEV commitment mostly lies in its belief of Fuel Cell as being the main future powertrain alternative for clean mobility. Following this belief, the company has invested large amounts of capital in producing a commercial F-cell car, the Clarity Fuel cell which has a stated range of 300+miles and a recharging time of 3-5 minutes. These characteristics would actually make it a superior product with respect to available BEVs, if it were not for the absence of a recharging system and the current unaffordable starting MSRP price of $59,365.

Despite the focus on F-cell technologies, by 2018 Honda nevertheless will have 1 F-cell, 2 BEV products, 1 plug-in and 2 hybrids in its market portfolio[288]. However, the changing remarks by the company’s CEO, the revolving market strategies and the clear predilection for F-cell technologies over battery EVs seems to transpire the absence of a strong clear plan for the 2020-2022 period. In this context Honda seems to be waiting for the BEV market to develop, by mostly marketing hybrid vehicles and putting big bets on the hydrogen alternative.

Following this perspective, a 1.5 score was awarded by CLSA which underlines Honda’s strong commitments in the F-cell technology and an apparent disinterest in the BEV market up to date, while waiting for the technology to reach market acceptance.

[286] In an interview at plugin.com
[287] Source: world.honda.com
[288] Honda Clarity Fuel Cell, Honda Fit BEV, Honda Accord Hybrid, CRZ Hybrid, Honda Clarity BEV, Honda Clarity Plugin.

3.2.7 Hyundai Group

Due to a lack of Korean engineers with eco-friendly powertrain experience, the company did not launch its first hybrid model before 2010. Subsequently, Hyundai motors managed to launch the Kia Soul EV globally in 2014 with only modest annual sales at present. So if the group seemed to be way behind as what regards electric powertrain technologies, 2016 sets a milestone date as a new corporate plan was set to leapfrog in front of competition in the EV industry. The plan involves huge investments in order to release 26 electrified models, including hybrids, plug-in, BEV and F-cell vehicles by 2020.[289] The plan also includes a long range 250 mile BEV in order to compete with market early entrants, which are already ahead of the game in this car segment. The eco-powertrain division manager stated how the strong release strategy would catapult the Hyundai group in second place for global EV models behind Toyota by 2020.

As can be seen in Figure 4 this risky gambit is particularly needed for the group as it lags behind the other automakers as what regards emission controls and wont probably fall within the 2021[290] emission standards without the help of electrified powertrains. The major risk regarding this powertrain electrification path is managing to follow customer tastes in foreign markets[291]. Missing the target could entail failed launch and huge capital costs to the company. For this reason the group has planned a scattershot approach[292]. This plan has also been considered risky due to low gasoline prices and knowledge of a possible low dealer support. However the low penetration of EVs in the Hyundai group[293] entails nevertheless a strong push strategy in order to meet the emission requirements. To succeed in such a strategy, the forecasted large

[289] Source: www.autonews.com article by H. Greimel 2016.

286Missing the targets could mean as much as $125 million in annual CAFE and ZEV fines for Hyundai. Without considering fines coming from the EU.

[291] Since Hyundai group is mainly an export company, market penetration in foreign companies is limited and difficult to acquire, especially when launching innovative products with little testing history such as EVs.

[292] With the planned launch of at least 12 hybrids, six plug-in hybrids, two EVs and two fuel cell vehicles spread across the Hyundai and Kia lineups. Including the Sonata Hybrid, Sonata Plug-in, Ioniq Hybrid, Ioniq Plug-in, Ioniq BEV, Grandeur Hybrid, fuel cell Tucson, Optima Hybrid, Optima Plug-in, Soul EV, Cadenza Hybrid and the Niro hybrid.

[293] Lower than 1% of global sales.

volume production should produce volume cost saving effects[294] which would repay the large investments made in this ventured EV strategy. Failing to meet sales targets could then imply capital losses for the Korean group.

With this in mind, however at present the group only released the Ioniq Hybrid and the Kia Soul BEV. The Ioniq plug-in & BEV, the Sonata plug-in & hybrid and the Tucson Fuel Cell are all expected by 2017. However, compared with the long range offered by the Chevy Bolt and the imminent Tesla Model 3, Hyundai models will lower range will have to find new ways in which to compete until the battery pack technology equalizes.

Confirming the analysis CLSA awards Hyundai a score of 2 underlining how it appears very committed to the future EV market with its announced outstanding EV model line-up, but is however playing a catch-up game against rivals, most of which are already highly involved in the industry. The next years then, will determine whether the risk taken by the group will be awarded or not.

3.2.8 Mitsubishi

Mitsubishi entered the EV market early in 2009 with its i-MiEV product produced on a unique platform shared with the i-On and C-zero[295],the early entry and the weak product[296] determined a sales peak of 11 thousand globally in 2012 and decreasing sales thereafter.[297] Despite the early market entry, the company did not bring through its grand electrification strategy and only came out with a plug-in SUV model[298]. For the 2017-2020 period the only planned release is that of a BEV and Plug-in SUV model, with most of the investments aimed at the improvement of PHEV technologies. This situation of apparent decreased interest and investments in the alternative powertrain technologies could come to an end after a strategic alliance was formed with Nissan in 2016[299]. This aim of the alliance is that of creating synergies through joint R&D,

[294] Such as creating a unique platform for the production of all electrified models, increasing learning effects and improvements in technological improvements in battery production.
[295] Respectively Peugeout and Citroen products were built on the Mitsubishi platform due to lagging electric technology know-how.
[296] Aimed at a very small market niche, given its look, dimensions, driving range and high price.
[297] As there were few product alternatives in 2012.
[298] The Mitsubishi Outlander.
[299] Where Nissan bought a 34% stake in Nissan's equity share.

procurement and product development. Most importantly Mitsubishi will have access to Nissan Leaf's EV platform[300] and technological know-how in an attempt to bring down the EV's production costs by one fifth in 2018.[301] This alliance could then bring new EV development opportunities to the Japanese brand who is currently lagging behind its Japanese rivals.

Mitsubishi was given a score of 3 by CLSA given its i-MiEV platform, and the present and expected releases of SUV PHEV and BEV models.

3.2.9 Nissan-Renault Group

Nissan can be easily considered one of the biggest supporters of the electric powertrain technology. Its Li-ion development started in 1992 with the first car release in 1997, the Prairy Joy EV[302]. Since then Nissan continued developing its technologies until it released the Nissan LEAF, the world's first mass produced EV. The car reached cumulative sales of 238,500 as of September 2016[303] making it one of the most successful BEVs up to date. This situation demonstrates Nissan's strong competitive advantage in electric powertrain technologies gained thanks to its long lasting R&D efforts and a very strong future corporate plan and EV commitment. On this side we can see how the Nissan-Renault alliance formed back in 1999[304] represents a huge success on the alternative mobility sides as the group as a whole is at present the world's leading plug-in electric manufacturer with BEV sales of 424,797[305] for the 2010-2016 period. Differently from what most of the other automakers have done to enter the EV market, N-R's CEO Carlos Ghosn, a strong supporter of EV mobility, set a corporate EV strategy based on targeting the mass market cars first, leaving the niche premium market to the background for the moment. Reflecting this strategy is the group's current EV line-up composed of two BEV hatchbacks and two BEV minivans[306] produced on a common platform. The Groups' commitment to EV technology hence

[300] Together with Renault.
[301] Source: Reuters.com 2016
[302] The world's first Li-ion battery EV.
[303] Source: Nissan corporate, Nissannews.com 2016.
[304] With the aim of unifying the company's market & know-how and especially lowering production costs by adopting common platforms, with an estimated produced value exceeding $4 billion in 2015.
[305] With 94,265 sales in 2016 alone, including those of the newly acquired Mitsubishi MC.
[306] Nissan LEAF & Renault ZOE, and Nissan e-nV200 & Renault Kangoo Z.E.

seems very strong given its long lasting investment and its strong bet on a future electrified mobility. In this context the Group seems to be preparing for a strong market shift that could come from an external event such as Tesla's launch of model 3[307]. Hence, as the market develops the group plans on being present with its mass market hatchback models, complemented by EV smaller mobility vehicles[308] and larger BEV SUVs & Crossovers[309] as this niche market is getting more popular.[310]

Rewarding the Group's leading EV global sales CLSA awarded a score of 3,5 defining the alliance's EV commitments among the most reliable among the established automotive industry rivals.

3.2.10 PSA Group

Following the industry turbulence, PSA group CEO Carlos Tavares announced the launch of the new CMP platform[311] in partnership with DFM[312] to allow the company to launch its first BEV vehicles by 2020 at the latest. The platform will be used for the production of B & C segment models, which represent PSA's strongest market. With this in mind, we can see how PSA envisions its EV entry strategy as being bottom-up, starting from mass market compact vehicles upward. It is important to notice how the platform will be used for pure BEVs as PHEVs will be launched before 2020 using the Group's current EMP2 platform.[313] Strategizing, leadership decided to launch electrified powertrains on the DS premium brand first, as it represents the technology leader in the group and sells to the most receptive customers. So for the 2017-2020 period the group will test the market with PHEV first, while it develops its CMP platform and waits for the market to evolve, and finally enter with full BEVs by the end of the decade. These investments, which seem limited compared to those of other automotive groups, would then represent PSA's attempt to modernize its powertrain

[307]As Dunsmore, director of EVs at Nissan stated "Nissan showed bravery 10 years ago to invest $4 billion in electric vehicles, and all that bravery has built up expertise that's unparalleled […] Other brands are now fellow pioneers. […] "Having Tesla, the visibility for the technology is a massive benefit".
[308] Such as the Renault Twizy.
[309] Following the Vmotion 2.0 strategy aiming at the introduction of electric crossovers.
[310] Source: Ghosn interview at Tokyo Motor Show from pushev.com 2016 article.
[311] As part of the "Push to Pass" EV corporate plan.
[312] PSA's Chinese JV Co-owner. Together they invested a total of £200 million on the platform.
[313] As stated by Tavares: "CMP will not be plug-in hybrid, however - that technology will be launched first by 2019, and on larger, top end cars based on the EMP2 platform."

efficiency and get prepared for the energy transition. We can see in fact, how the Group's VP[314] statements go in this direction by proposing the release of "seven plug-in hybrids and four other new electric vehicles scheduled for launch by 2021, in addition to our flagship engine models."

With a current offering of 2 city car low range BEVs produced on Mitubishi's i-MiEV platform, a BEV minivan and a hybrid[315], and announced PHEV and BEV models for 2019-2021 accordingly, PSA was awarded a 1,5 score by CLSA which highlights how the Group's market entry could end up being late.

3.2.11 Toyota

Similarly, to Honda, the Japanese company has set an integrated value chain greening plan called the "Toyota Environmental Challenge 2050", according to which the company plans not only to reduce emissions, but actually to achieve a net positive environmental impact by that year. Among the various challenges, the company has set a 90% reduction in C02 emissions of its vehicles by 2050 in comparison to 2010 levels. With this objective in mind, the company has set a vast EV scenario strategy according to which different EV technologies best adapt to certain given market situations. Oppositely to other automakers, such as Nissan, the company does not believe battery technologies will improve fast enough to bring efficient solutions for clean mobility. This is why EVs are targeted to urban areas and plug-in range extenders to longer commuting travel. Following this distinction, it is clear why the company's pure EV offering is very low, while its alternative portfolio is mostly populated by hybrid and plug-in models. As of today in fact Toyota's offering is composed of 5 hybrid, 1 plug-in and no pure BEV cars[316]. A BEV iQ is however expected by 2018. Bigger bets, and bigger investments have instead been made by the company on Fuel Cell technology after it recognized Hydrogen's vast potential competitive advantage due to its lower charging time and large natural availability. Adding to the differences already explained between BEV and F-Cell technologies, Toyota also stresses how its

[314] By G. L. Borgne, as found on PSA Group's media press releases in 2016.
[315] Accordingly, the Peugeiot iOn, the Citroen C-zero & Berlingo and the Peugeot 508. Without considering the Citroen e-Mehari with 569 sales in 2016.
[316] These are accordingly, Hybrids: Auris, Rav4, C-HR, Prius, Yaris, Plug-in: Prius. A one-seeter BEV does exist, the i-Road, but is not included in the car analysis.

solution would cancel out fluctuations in the energy distribution which could be caused by widespread recharging of BEVs[317] and in energy supply which could be caused by natural conditions. Following this vision about the future of Mobility, the company released its fuel-cell technology patent licenses[318] in a move similar to that of Tesla on the BEV side. This can be seen, similarly to the analysis made by Tesla, as an attempt to push the Hydrogen technology, which after the uptake and current hype of BEVs has been abandoned or temporarily put aside by many automakers, hindering its current distribution and future potential. This is particularly important, since the company has made high-stake investments in the F-cell technology and has already marketed a F-cell vehicle[319] .[320]

CLSA gave Toyota a score of 2 underlining how its high investment in F-cell technologies have put its EV strategy in the background. However, it also highlights how given its “massive R&D budget as well as technical and market leadership in normal hybrids, it wouldn’t rule it out from playing catch-up”. Hence Toyota could be at the EV industry forefront by possessing large know-how and production capabilities as what regards the BEV technologies and at the same time possessing unique leadership in the Fuel Cell segment. For the 2017-2020 period however, no gran EV strategy seems in place, moreover the company seems to confident in complying with 2021 emission standards thanks to hybridization and fuel efficiency improvements alone.

3.3.12 Volkswagen Group

Among the big automakers, VW group is the latest one to have entered the EV market. A clear example could be the VW branded e-Golf which only entered the Californian market[321] in 2014.

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[317] This topic will be further explained in paragraph 3.8.
[318] Toyota has given free access to approximately 5,680 fuel cell-related patent licenses (as of January 6, 2015). To promote the widespread early adoption of fuel cell vehicles and build a hydrogen-based society. Source: Toyota Global Site.
[319] The Toyota Mirai.
[320] Despite all these considerations, the company still has interests in all 4 types of alternative powertrains, hybrids, PHEVs, BEVs and F-Cells and will probably heavily invest on those which demonstrate to perform best.
[321] Due to the ZEV mandate requiring an all-electric model to enter the market.

Following the emission scandals, and the serious risk of incurring in huge fines due to the new emission regulations set for 2021, the group has announced a strong change of direction towards alternative powertrains. More precisely Volkswagen leadership announced in 2016 how the corporate strategy would be that of becoming industry leader in vehicle electrification by 2025[322], with planned sales of as many as 3 million PHEVs per year[323] equal to a quarter of total projected sales. This would be made possible by the projected launch of 30 new EVs and PHEVs by 2025 and as many as 20 models by 2020[324]. EV production should be based on the new I.D. concept produced on the modular MEB platform with the intention of creating an electrified sub-brand for the VW brand. A long range low cost EV is planned to be released by 2020, making VW a late entrant not only in the low range electrified segment, but also in the affordable long range segment. The MEB platform would then entail a mass market approach for VW group in the first period, following a segmented niche approach in a second period, when new modular platforms will be created for larger BEV cars.[325] Initial investments in this direction have been made such as the $2 billion investments made in EV production for the US. However at present the VW Group only produces 2 BEVs and 6 plug-in hybrids[326] and is way behind other car manufacturers in terms of actual financial commitments made, mostly relying on Top executive statements and plans regarding the expected leadership and profitability of its upcoming products[327]. If the plans turned out to be true, the Group would bring forth a strong EV entry strategy in most vehicle segments, with the aid of its controlled companies[328].

Underlining how the Group's focus has shifted from Diesel to alternative powertrains following the Diesel-gate scandal CLSA gave VW a score of 2,5. This score should reflect VW's announcements regarding its strong commitment to the BEV powertrain.

[322]Management Board member Diess announcing: "Anything Tesla can do, we can surpass. We are confident that in this new world we will become a market leader."
[323] Under the "together strategy" announced by Volkswagen CEO M. Muller in 2016, following Dieselgate.
[324] Of which 10 new models expected to be released in the next 2 years.
[325] Source: La Stampa Motori 2016 article by O.A. Eideh.
[326] The e-Golf, e-up!, Golf GTE, Passat GTW, Audi A3 Sportback e-tron, Q7 e-tron, e Porsche Cayenne S E-Hybrid
[327]Diess: "The entire electric fleet is to be profitable from the very beginning."
[328] Audi following a trial strategy launching a few models in all segments, VW following a specialist strategy, launching a myriad of models in the segments covered by its MEB platform, while Bentley and Porsche are expected to launch a plug-in and a full BEV by 2020, following a qualifying strategy.

If this materializes in the 2020 period, given the short time at disposition, is to be seen.[329]

3.2.13 The situation for other noticeable established automakers.

Many other automakers are following the market trend & need towards powertrain electrification following different strategies, which are mostly connected to their technological, capital & market situation.

Honorable mentions should be that of **Volvo**, which plans a full electric long range vehicle for 2019, accompanied by the hybridization of its full powertrain[330], with the aim of selling one million vehicles with some sort of electrification by 2025. Plug-in vehicle releases will start with the larger vehicles based on the SPA module and will be followed by an ad hoc branded series built based on the new CMA architecture. The company's strategy for the 2017-2021 period seems that of investing on the hybridization of its current ICE powertrain[331], while setting the base for the production of full BEVs and appropriately designed electric vehicles through appositely created new production architectures. Late launch of full BEVs also coincides with the stated current unprofitability of battery electric powertrains common to almost the whole industry[332].

On the contrary **Suzuki** seems to have no strong EV strategy offering at present just one hybrid, non-Plug-in model[333]. A PHEV Suzuki Swift is expected to into production by 2017, even though the company's focus seems to be centered over the developing Indian market[334] through a joint electrification development program. As seen in the Group's annual report[335] however, no alternative powertrain investment strategy seems in place as the company's focus seems to be that of increasing the efficiency of

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[329] It should be recalled how EV commitment and investment announcements have been also strongly used as a simple marketing mean. Many companies have announced strong commitments in front of the Press, but seem waiting for others to make investments needed to educate the market.
[330] Plug-in and conventional hybrids, Source: Volvo Corporate.
[331] It currently offers two plug-in models the XC90 and the V60.
[332] As stated by VP of R&D P. Mertens: "We have come to a point where the cost versus benefit calculation for electrification is now almost positive. Battery technology has improved, costs are going down, and public acceptance of electrification is no longer a question" .
[333] The Suzuki Ciaz.
[334] In JV with Tata & Mahindra.
[335] Annual Report (2016), Suzuki.

its consolidated petrol engine, its powertrains and its materials. To comply to the new emission standards, smaller engines and Mini, A & B segment volumes will be expanded.

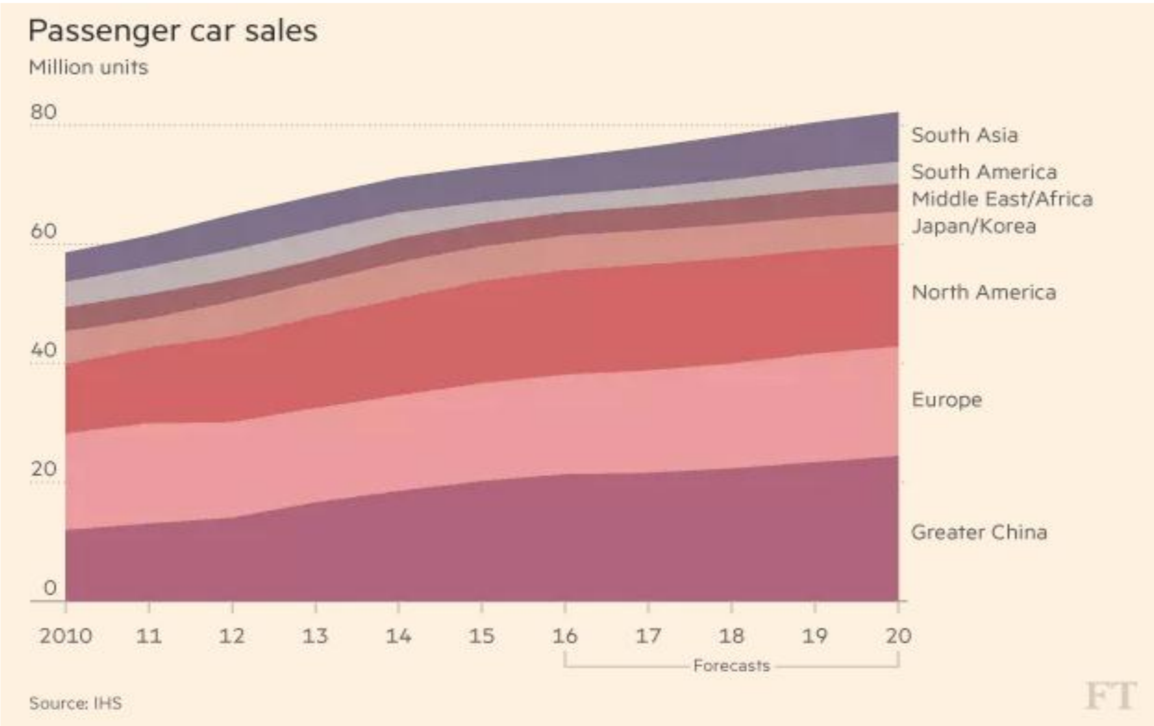
Similarly **Mazda** is following its long-term SKYACTIV technology plan which mainly entails: "improving the car's powertrain efficiency, such as the basic performance of the engine and transmission, and bringing about profound improvements in such areas as vehicle weight reduction and aerodynamics."[336] Following this plan, J. Guyton[337] stated how the company was expected to comply to the 2021 regulations by simply improving its current fuel economy by 20-30% "without any significant deployment of electrical drive". The company hence plans to offer some sort of hybridization or plug-in by end 2020. With no current PHEV models available, Mazda seems to be waiting until the EV technology matures in such a way to enter the market when development costs are minimal and demand is sufficient to be profitable compared to actual levels.

A last mention must be made to a company which is relatively young to the auto industry. **BYD**, a privately owned Chinese battery production company founded in 1995, entered the automotive industry in 2003 through the acquisition of Tsinchuan Automobile Company and the foundation of BYD Auto Company. Thanks to its expertise in battery production, its knowledge of and large presence in the Chinese large EV market, its cheap production capacity and strong Government backing[338], it managed in short time to become the world's largest producing company of electric vehicles. In fact, EV sales reached 96 thousand in 2016 ranking the company as n°1 for BEV volumes sold[339]. Producing both traditional and alternative powertrain vehicles, the company has seen the latter's importance, as share of revenues, increase thanks to the "continuous policy support from governments at all levels and the continuous rapid growth of the industry"[340]. Thanks to its vertically integrated structure it represents a key competitor in the EV industry, even though its business is currently relegated to the Chinese area. Following its current leadership in the Asian area as

[336] Annual Report (2016), Mazda.
[337] Head of Mazda Europe
[338] Through strong Government EV purchase subsidies.
[339] Representing a 23% market penetration in China, World's largest market for alternative powertrains. BYD places second for PHEV volumes behind the Nissan-Renault alliance.
[340] Annual Report (2016), BYD.

what regards battery production, motors and electric control, BYD plans on expanding its EV R&D capacity and volumes of production in order to realize large-scale production of technologically advanced products[341], also considering China's strong auto sales growth forecasts as seen in figure 17. It currently offers 2 PHEVs and one pure BEV model[342] at the global level. In the mid-term, the company plans to launch new PHEV and BEV models, including a battery powered sports car, confirming its strong commitment to the EV industry. With a long term vision to producing high-quality EVs in order to become China's number one alternative powertrain manufacturer, the company formed a JV[343] with Daimler to access the premium market capabilities.

Given its strong sales in China, and its numerous applications[344] of battery fueled powertrains, CLSA awarded BYD a score of 3,5 conferring a strong credibility to its investment commitments.



[341] More specifically BYD "will make additional investments to expand production capacity, improve product competitiveness, accelerate research and development and launch of more new models with the aim of satisfying the market's fast growing demand."
[342] Accordingly, the Qin, F3DM & the E6. PHEV and BEV models sold in mainland China instead sum up to 5, with the BYD Tang & E5.
[343] Creating the Denza automotive company with the Denza 400 EV (Source: Denza.com).
[344] It currently produces railways, buses, scooters etc, creating spill-over opportunities in battery production.

Figure 17, Passenger car sales forecasts, source: FT.

3.3 Looking at the aggregate level

Taking a step back and looking at the aggregate level we can grasp some insights as of how the major players in the automotive industry are moving with regards to powertrain electrification and why.

Looking at figure 18, which represents an adaptation of the previous analysis for the period 2017-2021 to the EV entry strategies as proposed in Chiesa's EMR (2016), it may be noticed that:

1. No car maker makes it in the complete athlete segment by 2021, demonstrating how the market will be far from maturity when the emission standards come to life. Moreover, the absence of a complete athlete demonstrates how no established automaker fully believes in the alternative powertrains for the short-mid-term as this would imply a larger presence of PHEVs, BEVs and FCEVs in the portfolio of car makers by that date. Exceptions must be made for Tesla and the other full BEV startups as these companies are trying their best at starting the revolution and going all-out on the EV market but currently lack the production capacity and presence of a strong distribution network to do so. Tesla in particular does not make in the Complete Athlete segment as it struggles in launching and producing new models while contemporaneously building the necessary charging network. The insufficient, yet strong growth of the charging network and the release of most EV models close to 2021 demonstrates how established OEMs are playing a waiting game in the hope of a competitor taking the burden to develop the market and of an external event that triggers the revolution, while being ready to enter the market with a sufficient range of products and a strong technology knowledge base.

2. Three investment strategies can be clearly identified, once the automakers are classified by EV segments covered and models per segment in the short term.

2.1. Hyundai/Kia and Ford will follow a specialist strategy by offering multiple EV models in their strongest segments. This specialization strategy hence aims at offering a variety of electrified models in the company's strongest segments. In their specific case, it is mainly due to their battery pack technology expertise, which limits their solutions possibilities, with full BEV short-mid range batteries adopted for smaller cars and plug-in and hybridization adopted for longer-range & sports cars. As the companies develop their Li-ion battery powertrains an introduction of long range full BEVs is expected shifting their strategic position towards that of complete athletes. Ford's investments in hybridization for longer-range models and Hyundai's current follower position[345], however entail that this group's expected transition to the complete athlete segment is extremely volatile, being based on unpredictable variables. With the above considerations it may be seen how such a strategy seems to be adopted by automakers wishing to build a large presence in their strongest market segment[346], or as a way to limit R&D and development expenses and capital risk on a single architecture with the aim of expanding the offering in a second moment. Companies following this strategy are nevertheless subject to customer demand risk, as if EVs are not attractive in the given segment, there is no hedging strategy in place to cover losses.

2.2. GM, Honda, Toyota, PSA, Mitsubishi and Volvo will follow a qualifying strategy by offering a few number of models in a couple of segments. Differently from the analysis made in a., the companies grouped in this segment follow this strategy for very differing reasons. GM offers a limited number of models in a few segments with the aim of ramping up production volume of a single market champion. This is usually done by producing small B or C segment cars through an ad hoc modular platform. This would bring to decreased production and battery costs, creating a price advantage with respect to competitor models. To widen the electrified model choice, the group aims at

[345] With most of its positioning in this analysis based on release date statements and EV plans, which could actually be inflated due to marketing efforts, or not be realized if the EV industry grows slower than expected.
[346] Usually the C compacts segment.

offering plug-in solutions for larger car models. On the contrary, Honda and Toyota will reach 2021 relying almost totally on powertrain hybridization, making little or no efforts at offering large scale BEV models. Honda in fact will limit its BEV and PHEV offering mostly to the European market, while Toyota expects on offering only one mid-range BEV globally. These two companies seem totally committed to pursue a follower strategy, waiting for others to develop the BEV market[347], while they heavily invest to become the long range F-Cell future market leaders[348]. PSA's and Mitsubishi's presence in this grouping instead is due to their past and present little investment efforts in the alternative powertrain industry, with the first being openly not committed to the technology in the short term[349] due to its numerous complications and low reliability, while the latter seems to have lost focus after the launch of its Soul BEV. Despite the past performance and their current beliefs, neither company wants to be unprepared to the evolution of the industry and steps are being taken to prepare for the change, with PSA's CEO stating "I'm excited about my company. It's strong in engineering. We can fight, using the technology that's imposed on us", letting transpire how the group will be willing to fight for dominance in the EV industry, once it becomes attractive to do so. With some exceptions then, companies in this grouping will appear in the EV industry in a non-aggressive way, mostly with PHEV models in an attempt to test market reactions and be ready to enter as late followers.

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[347] Having the patents and technologies to quickly enter the market once it becomes attractive.

[348] Honda and Toyota offer 2 of the 3 FCEVs present on market, with Hyundai selling the third, demonstrating the commitment of the Asian manufacturers to this alternative pathway.

[349] PSA's CEO C. Tavares stated in an interview regarding the release of a full BEV in 2019: "I don't think an EV will be profitable in the near future. Not unless you can sell the battery on to a second use." […]"It's hard to see how the price of new batteries will move. If battery production rises, raw material cost might rise too because of shortages, which undermines the usual volume/cost effect."[…] "I'm not pessimistic. Just over-pragmatic. We don't know how much customers will pay. And other fundamentals haven't been fully studied." […]"We don't know about the scarcity of raw materials. Or about battery recycling. Or the development of clean power generation. Or how taxes on petrol and diesel will move to electricity – governments need the revenue. We don't know what the charging network density will be."[…] "We will have our own EV technology and a family of EVs". However, Tavares also showed resentments on Governments influence over technological paths "We have moved from governments wanting an emissions target to the point where specific propulsion technology is determined by governments. They have chosen EV – by taxation, or by limitations on the use of other products."

2.3. Daimler, BMW, VW, Nissan-Renault, Tesla and BYD will follow instead a trial strategy, trying to diversify their portfolio offering the widest segment choice possible, by introducing a limited amount of models per each segment. Most of these are currently under-offering electrified products such as the German automaker trio, but have set strong plans and expectations regarding their product offering releases for the next 4 years. Even though full BEV offerings will be limited to 3-4 models per group, the combined BEV and PHEV offering will be way wider with announcements as strong as VW's 20 electrified models by 2020. The intense push strategy, both actual and planned, brought by the German automakers then seems a mix of both the will to dominate every market in which they intend to compete and a marketing mean to relieve their image from that of being the big polluters of the auto industry[350]. In this context however, Daimler's and BMW's ready to producing and already producing sub-brands put them in advantage with respect to VW's ID project, which seems still far from being ready to go to market. If a diversification strategy would be highly expected by the German trio, due to their strong presence in every car segment and their superior price points which would more easily justify paying the premium required for battery packs, this would not be so for the Nissan-Renault group. The latter is positioned at the top left corner of the grouping showing its distinct entry strategy with respect to the other big automakers. In fact, differently from a pure diversification strategy, Nissan-Renault will point on launching two mass market models in both the micro-car and compact segments[351] with the aim of gaining a large market share by volumes sold. It then plans to diversify in the SUV/Cross-over segment due to its current strong growth and the ability of exploiting its high price-points with respect to the regular sedan segment. With such a strategy then, Nissan-Renault results at the borderline, sharing common aspects with GM in the qualifying group as what regards mass market model choices and Ford in the specialist segment as what regards offering at least two models per

[350] With VW being involved in the diesel emissions' scandal as already explained in precedence.
[351] Without considering minivans.

segment[352]. Considering Mitsubishi as being part of the group, Nissan-Renault with shift further up-right due to the larger model offering. Instead, BYD represents an industry newcomer which is offering a diverse line-up of electrified vehicles and plans to expand its portfolio in the upcoming years. However, its market is mainly constrained in China, the greatest EV market for the coming years, making the launch of diversified models a good strategy to satisfy the needs of a constrained diversified customer population[353]. Tesla instead pursues a full diversification strategy from the moment that is currently offers only a premium sedan and a cross-over but is preparing to launch a small sedan and a SUV in the next few years. The degree of diversification and models per segment launched then seems not only a function of alternative powertrain commitment, since the German automaker releases highly depend on how they see the market evolving, but also on production capability and capital availability, as demonstrated by the Tesla case. To summarize then, the diversification strategy followed by the automakers in this grouping is mainly based on the launch of a limited number of pure EVs, on average not more than 4, complemented by a strong presence of PHEVs covering most of their car segments, with particular attention to the larger more polluting cars[354]. This strategy is mostly used by pioneers, due to their long time presence in the market, or early entrants and fast followers, which wish to establish a strong market presence in their highest value segments. One model diversification also represents a hedging strategy as automakers reduce customer risk by creating models for multiple segments, bearing however the risk of a larger initial capital expenditure to launch models built on different platforms. It is worth of notice, how if VW's and Daimler's plans are actually put into action by 2021 as stated, they would make it very close to entering the complete athlete segment, putting them in a market leading position.

[352] By sharing the same platform between Nissan and Renault, and Mitsubishi since its acquisition in 2016.

[353] In many Chinese cities strict emission regulations make EVs an attractive option to the upper class which can be more easily targeted with a diversified approach, selling high-end sedans, SUVs, Cross-overs and sports cars.

[354] In an attempt to lower fleet average emissions.

3. Startups obviously cover the qualifying segment as most will release their first model in the period 2017-2021. Moreover, in the majority of cases the expected launch will cover the sports car or high-end sedan segment[355] entailing high price points and relatively low sales volume. This is mainly due to the limited production capability and capital available for mass market production, following Tesla's technology life cycle model. It is important to notice how most of these startups are in the funding phase and still have not launched any car to market. This factor combined with the high risk of failure intrinsic to startups means that most probably just a few will manage to make it to market in a successful way. Obtaining a consistent market share in their niche segment will be therefore extremely difficult due to competition from some established competitors, and the presence of a multitude of startup competitors.

4. A group of players, namely, FCA, Mazda and Suzuki, does not make it in any committed entry strategy as they have no electrification process underway and seem to be not interested at the EV market at present due to its low profitability, high R&D costs and high level of demand uncertainty for the following years. The three companies seem to be exploiting their current low emission levels and plan to reach the emission standards by simply investing in improving their ICE efficiency. They represent the most opposing established automakers with regards to alternative powertrains and seem to be waiting for competitors to bear the risk of developing that technological pathway. Of the three however, FIAT seems to be reconsidering is fierce opposition and has planned the launch of some PHEVs not to be totally excluded from the market.

[355] Such as the Lucid Air luxury EV, the NIO NEXTEV EP9, the Fisker EV, the Faraday Future FF91, Rimac Concept One, Weltmeister, Future Mobility Cars, Uniti, Elextra, Venturi, GLM C4 & ZZ, NEVs (Ex-SAAB) etc.

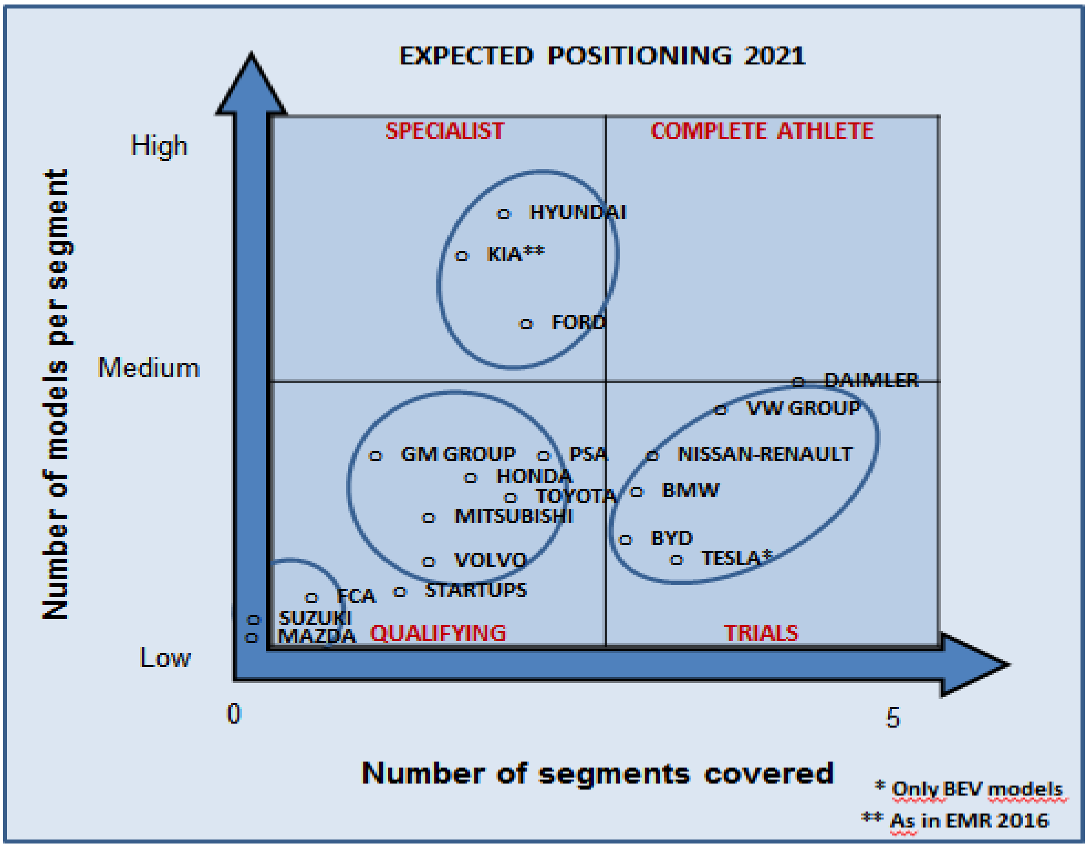

Figure 18, Automaker EV entry strategies based on expected number of segments covered and expected number of models per segment for the 2017-2021 period.

Looking at the picture as a whole, the absence of established automakers in the complete athlete segment, or who are totally committed to alternative powertrains (excluding Tesla, which is an outsider), the prevalence of waiting strategies and of risk hedging in an evolving market seem to indicate a veiled pessimism by the incumbents regarding the growth of the EV industry in the period until 2021 despite all the plans and actions they state are underway. Major factors of uncertainty in this context seem to be the lagging infrastructures and the demand which has still not taken the booming path which has been forecasted by so many industry analysts. For this reason, major European automakers are forming partnerships in an attempt to partly solve this problem.

From Figure 19 instead, which positions automakers based on the R&D investments and their manufacturing capability, we may see how the situation changes slightly, especially when considering the manufacturing capability of established automakers. Figure 19 in fact, is particularly important since it shows what are the actual possible choices of automakers, given their technological, productive and financial level. The situation depicted in fact, partly explains the behavior of some automakers such as Honda and Toyota, which have the technological base and the manufacturing capacity to enter the market either as fast followers or as cost minimizers depending on the attractiveness of the market in 2021. Suzuki, Mazda, PSA and Volvo instead are more constrained by their lower productive capacity and lagging technological knowledge, and will be forced to pursue a market segmentation strategy in order to avoid stronger competition, probably launching a multitude of models in one or two car segments threw the adoption of single platforms. FCA does have the production capacity, but lacks the battery knowledge to pursue a fast-follower strategy, cost minimization will be the strategy most probably followed. VW group and Hyundai/Kia have a huge sales volume and have set a strong EV push strategy, moving them close to a fast-follower strategy. If expected product launches were to be unexpectedly postponed, they could easily follow a cost minimizing strategy and enter the market late. In the same segment we may find Ford with its planned $4,5 investment on e-powertrains, which however does not have any competitive product on the market at present. The other automakers instead tend to pursue a leadership strategy by entering the market in a significant way for first. The reasons are different, some wish to exploit their current leading position and huge manufacturing capacity[356] in order to establish their leadership once the industry matures, others want to be market leaders due to a strong commitment and belief in the technology such as Tesla, and finally others[357] want to transfer their current dominance in their competitive segments obtained by offering the highest level of innovation also in the new industry showing a high level of risk tolerance and commitment to innovation.

[356] Such as Nissan-Renault, and GM.
[357] Such as the German Premium automakers.

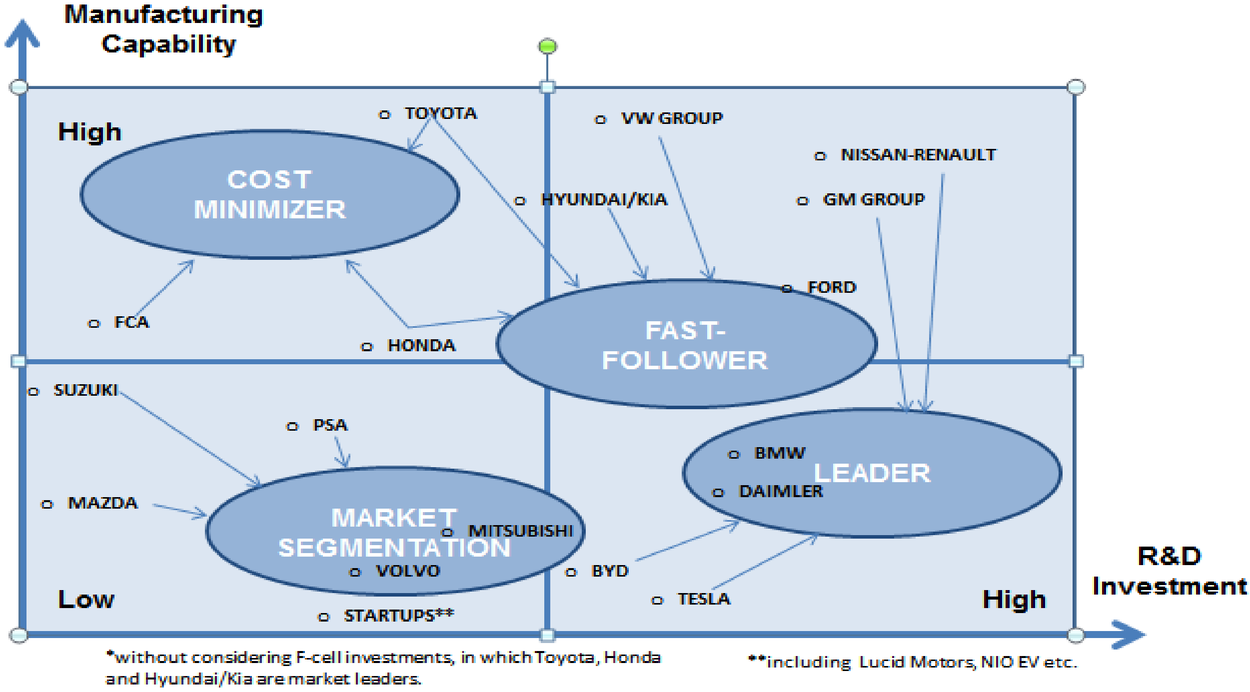

Figure 19, Automaker EV positioning based on manufacturing capability and R&D investments[358]. Manufacturing capability refers to 2015's ranking of manufacturers by vehicle[359] as found on OICA.

To conclude, following Wesseling's analysis as in Figure 20, we may see how the Renault-Nissan Group, together with the newly acquired Mitsubishi, had all the incentives in place to pursue a market leader strategy in powertrain electrification as they possessed above average technological knowledge and competence in battery packs an electric powertrains[360] and lower margins with respect to competitors in the ICE market. This situation makes EV early market entry attractive as it creates the possibility to gain a competitive advantage the companies did not possess in the ICE market. Fiat, Suzuki, Mazda and PSA had back in 2012 a high incentive to innovate due

[358] Both cumulative and expected 2017-2021, some examples may be Tesla's R&D expense which sums up to cumulative $2,5 billion, and 2016 $834 million (full BEV), Ford's 2017-2021: $4,5 billion spending in R&D and production (on electrified powertrains), VW $11,85 billion annual R&D (on all powertrains), GM's $8,1 billion (on all powetrains).

[359] 1) Toyota 10,083,831 2) Volkswagen Group 9,872,424 3) Hyundai / Kia 7,988,479 4) General Motors 7,485,587 with SAIC-GM (9,490,835) 5) Ford 6,396,369 6) Nissan 5,170,074 7) Fiat Chrysler 4,865,233 8) Honda 4,543,838 9) Suzuki 3,034,081 10) Renault 3,032,652 11) Groupe PSA 2,982,035 12) BMW 2,279,503 14) Daimler 2,134,645 15) Mazda 1,540,576 17) Mitsubishi 1,218,853 18) Volvo 503,127 BYD 450,000 approximately, Tesla <100,000.

[360] Calculated through the number of patents possessed and registed as of 2012.

to their low profitability, but little possibility to innovative due to their lack of technological knowledge. This situation characterizes a laggard strategy, which all firms in the cluster ended up following, being apparently totally or majorly not committed to alternative powertrain development in the short run. PSA's larger spectrum represents its higher sales of EVs as it circumvented the EV problem by leveraging Mitsubishi's asset position and reselling the iMIEV under the Peugeot brand. GM, VW and Toyota instead had low incentives and high opportunity to innovate back in 2012 making a follower strategy most attractive. The timing and degree of entry however become highly dependent on the evolution of the company's situation as the three have followed three separate paths. GM decided to reduce investment risks concentrating R&D and investment efforts on one main segment, VW instead had to anticipate its market entry mainly due to the emission scandals and the stricter regulations set by EU, Toyota lastly has managed to maintain its follower strategy and waits for the market to evolve before considering a strong market entry. The grey cluster is formed by companies which back in 2012 had some incentive to innovate due to average mean annual net income and some or low possibility to do so. This cluster, representing fast followers, is however the most mixed in terms of strategic paths undertaken, with companies going in very different directions. BMW and Daimler experimented a diversification strategy, while Ford initially focused on a specialization strategy. Honda however turned out to be pursuing a late follower strategy as it has been waiting for the market to develop, as happened with many other Asian automakers. Similarly, Hyundai has been dormant in the BEV segment, mainly investing in the F-cell technology, and has only recently developed a grand EV plan.

In conclusion then, by looking at the different clusters and their EV development over time, we may see how not only did automaker's alternative powertrain commitment depend on their cumulative technological base and their past average income, but also on factors determining the evolution of their competitive situation such as emission fines & pending cases, and even more importantly competitors' moves in one or the other direction.[361]

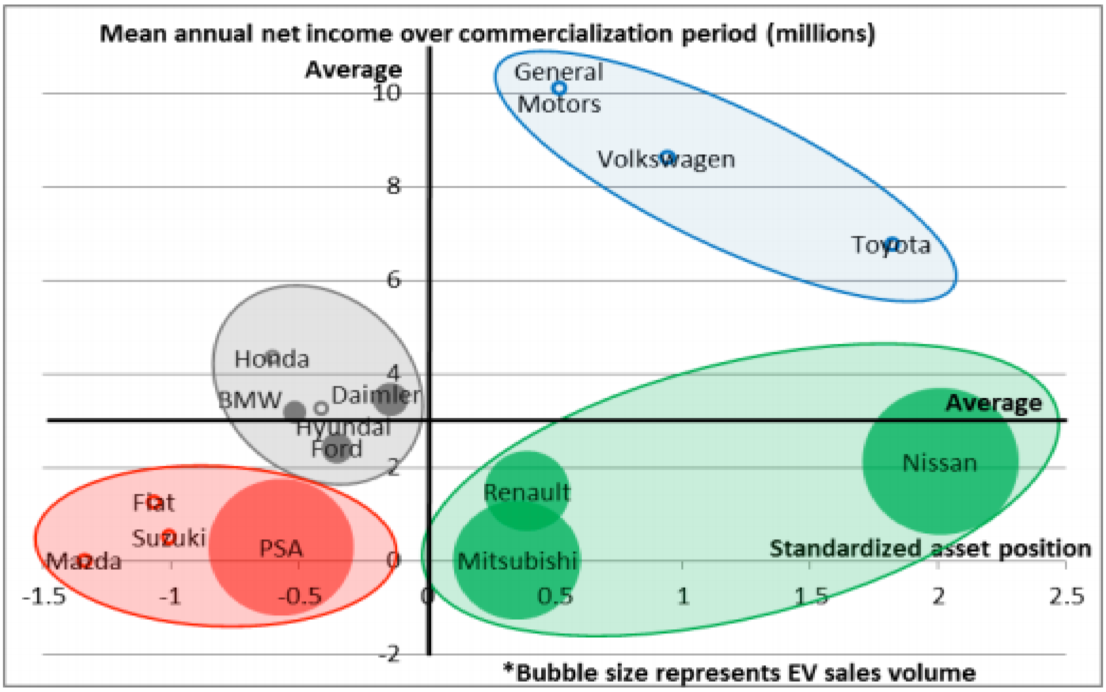

Figure 20, EV strategies based on incumbent's distribution during the commercialization period as found in Wesseling's "Business strategies of incumbents in the market for electric vehicles [...]" dependent on the main variables "mean annual income" and "standardized asset position".

3.4 Collaborate or do it yourself?

As seen in the previous analysis, automakers have recently changed their EV strategy, with most car manufacturers following an independent electrification path. This is particularly true for all that regards the battery electrified portfolio, where automakers want to do it their way in order to create knowledge spillovers and run down the learning curve. In this segment, collaboration strategies and alliances seem mostly addressed to the creation of the external environment, from partnerships with battery producers to collaboration strategies with other car manufacturers for the creation of

[361] BEV investments have increased also due to the hype created around battery technologies, while hydrogen fuel cells have moved to the background, determining a loss of interest in many automakers.

the recharging supply network. Automakers which previously outsourced EV production[362], now seem willing to invest into in-house R&D in order to create a proprietary design. This strategy seems appropriate for a technology which has surpassed the boundary of uncertainty and is destined to become mainstream in the long term.

As what regards F-cells instead, their very existence is at risk due to the booming interest for battery driven powertrains. This, together with the immense R&D expenditure needed for a new technology, are the main reasons why automakers seem more willing to collaborate and partner in both the R&D and the commercialization phases, with big alliances being forged in order to force the technology to market[363].

3.5 A non-market perspective

Company's alternative powertrain efforts may be also found by looking at non market investments. Two clear examples are military applications of potentially commercial technologies, such as GM's development of the ZH2 F-cell truck, and the Formula E. The latter is particularly important as it creates high-grade battery technology improvements whose spillover effects greatly affect the passenger car market. EV commitment then can also be seen by noticing which automakers participate in the championship[364]. The only established automakers present in the competition are Audi for the VW group, DS for PSA, Renault for Nissan-Renault and Jaguar-Panasonic[365]. The other participants are mostly EV startups, which pursue a segmentation strategy by offering the best in class EV technology on high-segment supercars such as Faraday Future, Nio NEXTEV and Venturi. Mahindra instead represents an attempt of the Indian

[362] Such as PSA with the iOn and C-Zero.
[363] As seen in par. 3.6.
[364] BMW & Mercedes are expected to join the championship in 2018, maybe together with an Italian automaker (Quattroruote 2017).
[365] Which demonstrate the R&D efforts made by the English car manufacturer in alternative powertrains. A long range BEV, the I-Pace is expected to be released in 2018, signing the entrance of the group in the EV market, plug-in hybrids for the LR brand will probably be released to market by 2018.

automaker to make progresses in electrification with a view to participate in India's announced grand electrification strategy.

3.6 A brief comment of hydrogen fuel cell developments

The second path which is being developed in the electric alternative powertrain technology is that of hydrogen fuel cells. The analysis made up to now only briefly commented such technology due to its low present diffusion which is not expected to show major changes in the short term. It is however worthy of notice how investments are being made also on this alternative path, since fuel cells do present some clear advantages with respect to BEVs[366]. At present the technology is strongly dominated by Toyota, Honda and Hyundai, the only companies with a commercial vehicle on the market. However, due to the lagging infrastructure and the slow market development an alliance has been made with a group of 13 companies, called the "Hydrogen Council", including Daimler and BMW to invest $10 billion in the next 5 years in order accelerate the development of this alternative technology. This alliance then may represent an attempt to revive a faltering technology in which some automakers have already made important investments, creating a united front to diminish capital and development risks and lobby governments into investing in the required infrastructure[367]. Toyota and BMW also formed an alliance to build sports cars and heavy duty vehicles driven by F-cells. Alliances are particularly strong in this field due to the need for an imminent change and the difficulty in developing products and structures alone. If the technology shows strong improvements in the next years, the automakers forming the alliance will benefit from a leading position the new market. However, if Battery Electric powertrains become the dominant technology, and manage to reach price equality and long range autonomy[368], F-Cell technologies could face great difficulties finding a profitable space in the "0" emissions market.

[366] The analysis of pros and cons has already been made in par. 2.4.
[367] Source: Autoblog, 2017.
[368] As found on Quattroruote 06/06/2017 article, Fisker announced a stated autonomy for it Emotion of 640km and a fast charging system thanks to improvements in the Li-Ion technology, enabling 160km autonomy in just a few minutes.

3.7 Looking at the actual situation and how this applies to market entry strategies.

Despite the optimism in the EV industry which transpires from the German automakers' strong investment commitments, in May 2017 Germany's chancellor stated how the country's predefined objective of 1 million circulating electrified cars by 2020 will not be reached with current sales[369], and that big investments will be needed to accelerate the process. At the same time we may see how the German premium manufacturers together with other European manufacturers in the EAMA[370] which so strongly publicize their electrification efforts have simultaneously lobbied government agencies in an attempt to postpone the emission standards from 2020 to 2021[371], given the stated difficulty for large car makers to reach the 95g CO_2 weighted average limit. Similarly in the US the Alliance of Automobile Manufacturers[372] contacted the President in an attempt to state how zero-emitting cars cannot be produced at competitive prices, stating how consumer demand for alternative powertrains is still "too low" for current prices and that fuel consumptions requirements are too strong to make compliance competitive for automakers[373]. Also Tesla's Model 3, which is expected to revolutionize the market will not probably reach its sales targets for 2018 due to production slowdowns[374] and will probably delay its mass market entry. On the other hand an in depth analysis of the Chevy Bolt by UBS, which determined that EV production costs have decreased way faster than forecasted, translates in expected price parity of ICEs and EVs in Europe by end 2018[375].

Also, as seen in Figure 21, the total price purchasing gap between ICEVs, BEVs and FCEVs is expected to decrease quickly in the 2020-2025 period if supported by strict emission standards and government financial incentives. This would be mainly due to

369 At the end of 2016, the German EV fleet hardly reached 80 thousand units.
370 European Automobile Manfucturers' Association.
371 Source: The Guardian 2013 article.
372 Which represents almost every US automaker except for Tesla.
373 Source: F. Lambert 2016 article on Electrek.com
374 As forecasted by A.Jonas in a Morgan Stanley report.
375 Source: 2017 article by P. Campbell on FT.

the increase scale of battery production, increased battery pack technological knowledge[376], increased efficiency of powertrains and also on the other hand, increased cost of producing ICEVs due to stricter emission standards. Strong government intervention will also be needed since, as explained previously, many automakers will manage to reach the 2021 emission targets without having to depend on powertrain electrification.

This mixed situation then, still keeps incentives to invest in EVs high, at least for efficient powertrain and battery producers[377].

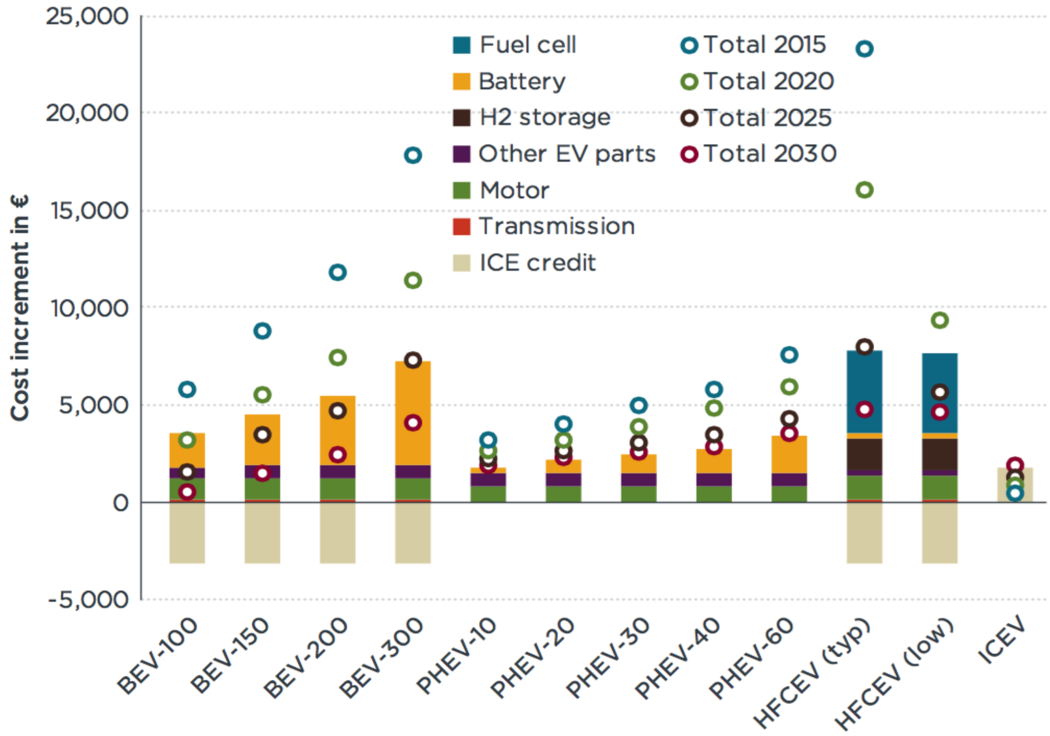

Figure 21, source: ICCT Report 2016 by Wolfram et al., cost breakdown of different power trains for a 2030 lower medium car. Circles show total incremental costs over a 2010 internal combustion engine vehicle (ICEV).

In this evolving scenario then, EV investments should be supported by strong initial sales in such a way to run down the huge initial investments made and build market share exploiting the lower competitive environment. For this purpose, Tesla pursued a

[376] With battery costs forecasts of $130-$180 per kWh.
[377] Vertically integrated automakers who manage to produce EVs at lower than average costs, or premium manufacturers who manage to sell EVs at a premium.

strong international strategy in such a way to expand its customer base and relative sales and pre-orders as much as possible. Covering this topic, we may see in Figure 22, retrieved from an Accenture 2016 report, how international automakers should focus their market entry strategies on the "Best-in-Class" countries as these show the biggest sales base and growth potentials and are characterized by strong government support which has already created a sufficient charging infrastructure. Following are "High-Potentials" which show similar growth and government support, but lack the former's market size. Any automaker willing to invest in EVs then should have a clear strategy to enter in these markets before any other as these are the ones which will drive EV sales in the following years.

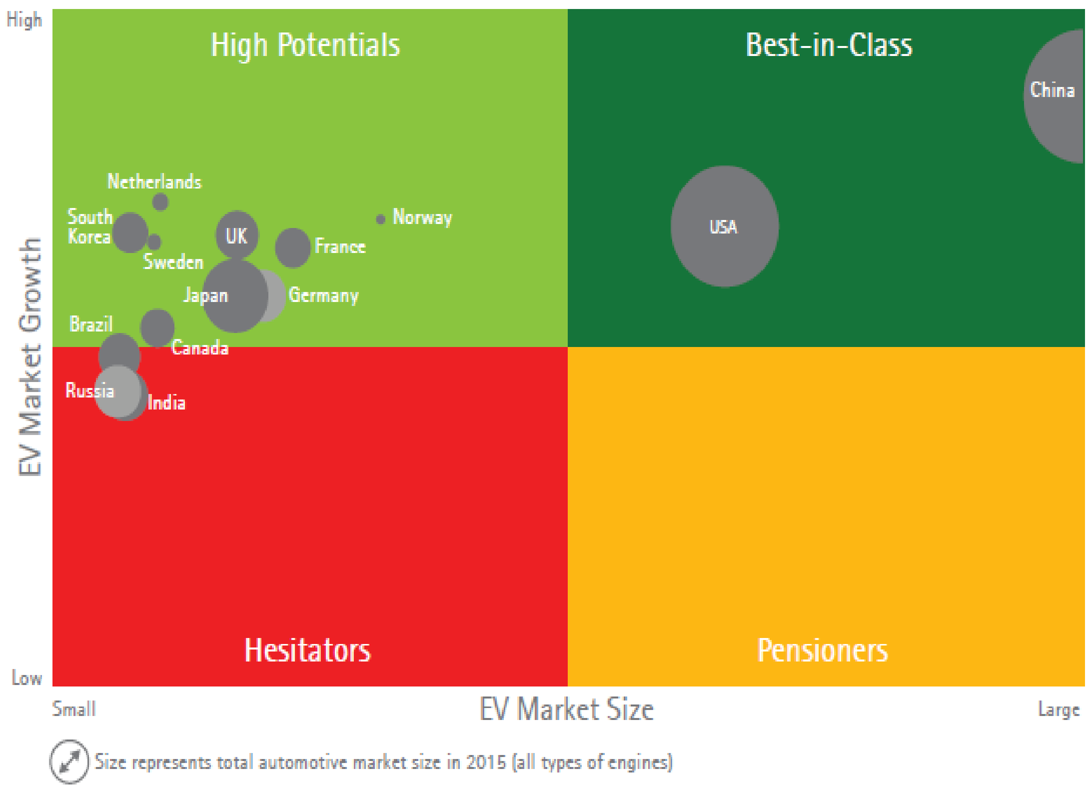

Figure 22, Source: Accenture Electric Vehicle Market Attractiveness Report 2016.

A special remark must be made for India, which was included in the hesitators, but has recently launched a Government-backed electrification scheme called " Faster Adoption and Manufacturing of Hybrid and Electric Vehicles" which aims at boosting

EV sales in the country up to 7 million units by 2020[378], and 100% of sales by 2030. This plan would be backed by a Government battery production factory with an expected production capacity of one gWh by 2020. Government officials stated how: "If we accelerate electric vehicle growth it will be a disruption for the auto sector and would require investment, but if we're not able to adapt quickly we risk being net importers of batteries". In this situation, Indian automaker Mahindra could become an important player in electrified powertrains.

3.8 The grid distribution problem and the need to upgrade the power network.

The uptake of EVs at large scale may create problems for local distribution grids and their operations as the increased electricity demand can create “grid stress” and saturation points if not properly managed. As seen in McKinsey’s 2014 Evolution report, it is not the increased electricity demand which poses a threat to the present distributing network, as the increase is expected to be in the 3-4% range, rather the potential increase in peak demand as most EVs get connected simultaneously to the grid at certain times of the day. Since energy distribution grids follow a load curve, charging habits could then intensify load peaks or level them out, creating great energy distributing inefficiencies and possible power shortfalls. A solution to this problem could then be an intelligent grid management distribution system which can enable “demand-side management” in order to level out distribution peaks by equalizing floating power demand with power supply through load shifting and vehicle to grid systems. Problems in upgrading both the grid distribution system’s infrastructure and management could then negatively impact BEV distribution increasing the appeal for hydrogen technologies.

3.9 The need for a clean energy value chain and for a wider sustainability vision.

[378] Source: Reuters.com 2017 article, Quattroruote.it article 2017.

However, appealing they may seem, EVs do not run on themselves, but do require a propulsion energy source. “Zero emission” in fact, is wrong as it may sound with many country’s utility power generated by energy sources so “dirty”[379] that the net effect of diffusing EVs is null if not negative. The U.S. EPA[380] also concluded that Li-Ion batteries using cobalt and nickel have the “highest potential for environmental impacts” regarding pollution and health safety, even though just recently Panasonic stated it is foreseeable to reach a 100% recycling target for used batteries.[381]

Talking about powertrain efficiency, a study by Wolfram et al. (2016), which reviews the current literature on technology costs and carbon emissions for EVs clearly shows how the emissions’ situation should change with alternative powertrains’ introduction. As can be seen from Figure 23, 2020 BEVs and PHEVs should achieve a 32-54% lower emission target with respect to 2021 set emission’s standard. This would highly justify the investment in alternative powertrains, since the diffusion of EVs would entail a strong decrease in pollution emissions due to increased efficiencies. However, the studies on which Wolfram’s analysis is based assumed lower upstream energy emissions due to more efficient production processes and an increased share of renewable energy market share for energy production in accordance to IEA’s 2011 New Policy Scenario. If this were not to happen, the case for electrified powertrains would be highly reduced, since the obtained benefits and the expense incurred to obtain them would be much less justified. A clear example may be California, the EV haven, whose electricity power generation in 2015 was still based for 60% on burning fossil fuels, with wind and solar making up less than 14%. California however, represents one of the “greenest” states, with China having 72% of energy produced by coal, US more or less a third and the world showing an average of 40%[382].

[379] Such as energy produced by uncontrolled coal power-plants. A study by the European Environment Agency shows how if big fleets of EVs are charged with electricity from coal-burning power plants, the overall levels of Sulphur dioxide air pollution might rise.
[380] Environmental Protection Agency.
[381] Source: the guardian.com 2016 article.
[382] According to IEA’s 2014 report.

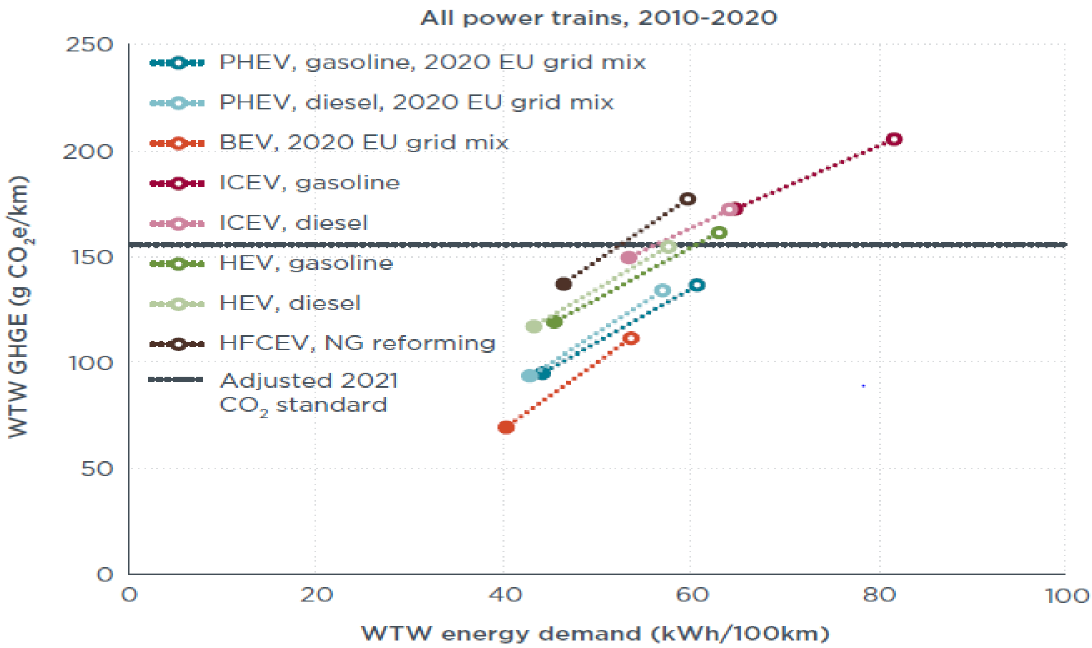

Figure 23, From Wolfram et al. (2016): "Expected change in WTW GHG emissions and energy demand of different powertrains. Hollow dots represent 2010 values, solid dots 2020. The horizontal line represents the 2021 European passenger car CO2 standard adjusted to WTW and real-world fuel consumption. This would greatly reduce the benefits of using electricity powered vehicles as the energy sources turn out to be as polluting as those powering ICE engines[383]. Serious investments in renovating the electricity power sources must be then made, with a further involvement of governments and international agencies.

It must be said that while EVs rely on energy whose production only produces carbon dioxide, a non-toxic greenhouse gas, ICEs also produce nitrogen and sulfur compounds which are harmful and whose elimination would benefit the social community.

This said, by putting things into perspective we may see how a larger sustainability vision must be embraced by local governments, as is clearly stated the Guardian's 2009 article, which points out how all the worlds' car NOx and sulfur dioxide emissions

[383] Moreover, as seen in the guardian's article of 2016: "The hour of the day is equally critical. "The cheapest power is not the greenest power." In California, the cheapest power is produced at night, mostly from natural gas, hydroelectric dams and nuclear. Night is when many people will charge their electric cars. However, the greenest power gets generated during the day, when solar power can feed the grid; solar doesn't work in the dark, windmills stop spinning if there's no wind and, in today's grid, there is almost no capacity to store solar and wind-generated electricity to use later. Grid storage is slowly expanding, but most electricity has to be used as it is produced."

are lower than those emitted by only the 15 largest cargo ships, due to their use of heavy fuel oil. Despite being one of the most efficient ways of transport then, stricter regulations should also be in place for this sector due to its potential harm to the environment and public-health. A broader sustainability international program should then be pursued in the whole transport segment.

3.10 Recent Developments

In May 2017, FCA has been impleaded by the American Department of Justice following the alleged installment of a "defeat device" on the emission control devices for 104 thousand Jeep and Dodge engines in an attempt to lower the detected NOx emissions. According to the EPA[384] fines could reach up to $44,539 per engine totaling $4,63 Billion. Similarly, Daimler's German offices were recently searched by the local authorities following an investigation on an alleged manipulation of emission control devices. Similar investigations were conducted on Opel, GM, Mitsubishi, Nissan, Renault, PSA and other automakers[385] bringing to mixed results, the media hype was anyway particularly important. All these incidents should further favor the push by established automakers to diffuse alternative powertrains in an attempt to clear their image from the recent scandals. Further happenings which could promote EV diffusion are instead on the technological side. As with all technologies, companies have been investing on reducing the gap between ICEs and BEVs by improving battery range, vehicle speed, infotainment etc. Trying to solve the particularly significant weakness of charging time, companies such as Qualcomm[386] have recently announced investments in wireless induction battery charging roads, which would allow battery recharging in motion[387]. Vehicle automation could also help boost EV sales, when combined with innovative business models. The price gap between EVs and ICEVs is greatly reduced by the vehicle time on road. Automation on this side, could lead to the diffusion of

[384] Environment Protection Agency, USA.
[385] Some investigations were dropped,others instead were brought up for smaller cases involving a limited number of engines. A class action has just been raised against GM for the alleged application of defeat devices on 705 thousand pick-up engines, with NOx emissions presumed to be 5 times higher than permitted by law. A similar investigation has just been opened for Daimler in USA.
[386] Or Electroroad (Source: quattroruote.it 18/05/2017).
[387] Actual commercial development is expected by 2025 (by the firms investing in the projects).

sharing and leasing business models with increased vehicle use creating a strong imbalance toward EVs for their lower cost of operation. In this context, Audi has just announced the release of a level 3 autonomous driving A8 by 2020. Most competitors are expected to enter the autonomous car driving market due to its huge business potential.

Interest in new automotive technologies, such as autonomous driving, interconnectivity and powertrain electrification will also bring to a shift of mobility towards service business models[388] with the surge of new competitors in these new markets forcing traditional OEMs to acknowledge these multiple markets. Mobility providers (such as Uber), tech giants (such as Google or Apple), and specialty OEMs will complicate the competitive environment and pose multiple threats to traditional automakers and their old business model.[389]

This will lead to the entrance of a multitude of new players in the 2020-2030 period, which will initially focus on a few steps of the value chain[390] trying to build the necessary knowledge to enter the market subsequently.

[388] Which could increase industry revenues from the actual (2015) $3,5 trillion to $6,7 trillion in 2030.
[389] Source: McKinsey Report 2016.
[390] Such as automation, battery production, mobility services etc.

Conclusion

When talking about automotive powertrain innovation, the decisions of which technology to invest on, when to invest and how to access it become particularly hard due to a series of factors such as technological and demand uncertainty which make forecasting strenuous and investments highly risky. Managing to assess correctly a market entry strategy involving both timing and entry volume, a collaboration strategy in order to minimize investments while maximizing technology learning and market share, and a correct technology strategy trying to predict what the future of powertrain mobility will look like will make a difference in the medium-to-long term competitive position for established and new-entrant automakers. A disruptive innovation such as the electrification of the automotive powertrain has then the potential to re-shape the current industry equilibrium with the possibility of seeing the surge of new dominant players in this “old” established market. This is particularly true if we consider electrification as a competence destroying innovation which will render ICEs obsolete with time. However, all established automakers have the funds and time to eventually gain a sufficient knowledge base also in these new technologies.

In this context two powertrain technologies have been studied, hydrogen fuel-cell and battery electric, with most of the focus falling on the latter due to the short-term scope of the analysis. More precisely, the first represents a technology, which is being studied and developed by a restricted number of players, entailing high investment risks, but high returns if the said automakers manage to make fuel cells mainstream. The latter instead represents in comparison, a lower risk and lower reward technology, due to the great number of players following that innovation path, which however has the potential to set itself as the dominant design, cutting out competing “0” emission technologies from the market. Automaker individual innovation strategies have then been analyzed to find investment trends based on a company’s current situation and pursued objective. For the period 2017-2021, year in which the EU emission regulations will be implemented, established automaker’s past, present and stated future behavior regarding investment amount and timing, technological choice and inter and intra-industry collaboration have been analyzed to determine the evolution of and the entry strategies specific to the EV market.

In particular, after having acknowledged what are the demand forecasts for the period according to the most recent reports, and what are the predicted 2021 automaker emission with the related possible fines, defining thus, what are the industry-wide EV influencing variables, an in-depth analysis of single automaker's corporate strategy regarding electrified powertrain innovation has been conducted. Keeping in mind the pros & cons of each technological powertrain and the influence of the most recent developments on the different technological paths, entry strategies for the period under analysis have been defined according to the following variables: automaker portfolio's segments covered by EVs and models per segment, automaker's manufacturing capability and R&D spending and expected investments in powertrain electrification, and past and present standardized EV asset position and mean net income as indicators of investment incentives.

It was found that for the 2021 period, no established automaker will commit completely to the new disruptive technology due to a number of factors such as demand uncertainty, ICE profitability, insufficiency of complementary assets and enabling technologies (which impact via the network externality effect) and mostly unwillingness to in customer education due to free-riding, but will be mostly playing a wait-and-see strategy preparing to enter strongly as soon as the situation becomes more favorable. Until EVs do not become sufficiently profitable then, established OEMs will continue milking the "cash cow" while simultaneously slowly developing the alternative market. Market presence will then be mostly pursued for production scale, exclusive supplying contracts and the creation of a strong brand presence. It becomes evident then, how the automotive industry applies to the case brought by Abell (1978), for what is really crucial in such a technology-intensive industry is the capacity of established automakers to have the right competencies at the right time, in order to maintain their competitive advantage in a continuously evolving environment.

As regards portfolio model strategy, most big automakers will follow a trial diversification strategy launching single models in multiple segments such as Daimler, BMW, VW and partly Nissan-Renault. For most automakers in this grouping, the applied strategy represents a continuum with that currently adopted for ICE vehicles[391]. Tesla on the other hand is pursuing such a strategy due to its newness to the automotive market and the technological-product lifecycle path it is following. Other automakers such as Hyundai, Kia and Ford are instead following a specialization strategy, pursuing a mass market entry in a single or few market segments in an attempt to build a strong market share and establish a barrier to entry on late-followers. Qualifying competitors instead will only launch a few models in one or two segments due a late market entry strategy such as Toyota and Honda, a limited technological asset position such as PSA, or a limited vehicle portfolio such as Volvo or Jaguar. GM also belongs to this group as it has concentrated most of its efforts on the launch of one mass market EV, pursuing a high, market risk-reward strategy. A number of players such as FCA, Suzuki and Mazda show a limited to no interest in entering the EV market thanks to their current low emission's position and will probably act as late entrants.

For what regards entry timing instead R&D efforts, manufacturing capability and incentives to innovate represent the fundamental variables. In particular companies showing a strong EV asset position and a lower than average ICE net income have strong incentives to be early entrants in the EV market in the hope of re-shaping the industry and their competitive position. Adding to the current technological knowledge position, manufacturing capability strongly influences entry timing as companies with a lower capability will need to enter early and build market share in order to compete with group's presenting larger and more effective production capacities. In this respect we may see how BMW, Daimler and Tesla have the right incentives to become early entrants, while the Nissan-Renault group has both the incentives to enter early and the manufacturing capacity become an early follower. Groups with mixed incentives and technological asset positions such as VW, GM, and Hyundai/Kia will follow early entrant or fast follower strategies mainly based on their current EV market situation. Toyota and Honda instead, which have little incentives to go to market, but high manufacturing and technological capacities will act as late followers, monitoring the market for the best entry situation. Finally, some automakers such as FCA, PSA, Suzuki and Mazda will have to follow a laggard strategy due to an insufficient technological

[391] The mission of becoming the best in all segments entered.

position and will tend to focus on future market segmentation or cost minimization based on their manufacturing and productive capacities. FCA is unique among automakers as it is still basing most of its sustainability efforts on methane powered engines.

Smaller automaker groups will also have to act as followers, mostly following a market segmentation strategy as they lack the resources to educate the market and aggressively introduce vehicles with an uncertain demand.

New players mostly represent sports-car or supercar manufacturers which are following an early entry market segmentation strategy by marketing to a small set of EV wealthy lead users.

The entry strategy pursued by most if not all established automakers at present in the BEV segment is that of internal development (with the aid of external information, obtained through collaborations or external hiring) given the widespread technological knowledge, the lower level of investment risk, the need to create a long-term competitive advantage, and the industry's history of developing fundamental technologies in-house. Moreover, the requirement of designing and developing new powertrains internally comes from automaker's need of developing products which are consistent with the corporate design and culture.

On the contrary, collaboration strategies in innovation seem to be proportionately dependent to the risk involved & the current technological knowledge base, and inversely dependent to the cash availability & the need to create a competitive advantage over the technology. This translates in a frequent recourse to partnerships and alliances in the field of charging infrastructures which display a low competitive advantage potential, in fuel cell technologies, which entail high investment risks and for which budgets are presently limited, and among automakers and battery suppliers, in an attempt to create a long-term competitive advantage through exclusive supplying contracts. On the contrary, established automakers have stopped creating ad hoc partnerships for EV development in an attempt to build proprietary technology and knowledge and increase their absorptive capacity. Joint Ventures are still fundamental to access certain developing markets and are still particularly strong in

China, with new partnerships being formed at present. If in the past alliances were formed in the BEV segment due to lacking technological knowledge, today the need to create a competitive in-house knowledge base requires going solo on marketable technologies.

In launching EVs established automakers will concentrate their efforts at first on the 3 big markets, China, USA and Europe necessary to gain the required sales volumes to justify production. Moreover, a distinction will be made in the single regions depending on Government incentives, existing charging infrastructures and customer attitudes towards battery powered vehicles. Developed dense cities with stricter emission regulations will show a higher rate of adoption, with sales penetration being lower in rural areas and small towns due to longer driving ranges and lower incentives.

Apart from the previous factors, important influences on the evolution of each automaker's corporate innovation strategy have been the current surge in emission scandals with the related PR and economic damage, changing Government directives concerning emission standards and the evolution of enabling and complement technologies, which continuously change the environment in which the companies compete.

Recommendations

Automotive companies cannot forecast future industry developments with certainty, they can however build strategic plans to prepare for disruption and be ahead of competition by taking steps to shape the evolution. To do so they will need to closely follow market trends regarding enabling technologies and business model evolutions. In an industry showing growing complexities partnerships and cooperation along the value chain will be needed to form competing ecosystems, especially when considering mobility as a service. To be ahead of competition, automakers must be at the avant-garde in all new potential mass technologies, comprising electrified powertrains, autonomous driving technologies and car connectivity. Considering entry strategies, automakers with a strong EV asset position which plan to heavily commercialize alternative powertrains in the 2017-2021 period in order to build market share and exploit first mover advantages should ramp up lobbying efforts on eco-friendly environmental policies. This is because, as seen in Chapters 2 and 3, most established automakers will manage to each 2021 emission targets without having to depend strongly on alternative powertrains. This means that expected cost reductions and efficiency improvements will only be reached with Government support. In particular, strict emission standards and both fiscal and non-fiscal incentives for EVs are needed to tip the balance towards electrification in the short to medium term, as electrified push strategies will only succeed if companies manage to reach certain volume thresholds. Also, innovative business models, such as car sharing services could be used to increase EV's time on road and reduce their TCO, increasing their relative advantage against ICE vehicles. If EV demand results being lower than forecasts, first-movers should try to form collaborations in order to create strong market positions, reputation branding and create industry standards in order to reduce investment risks. Automakers with strong EV asset positions but low incentives to market should instead keep building their EV asset position, collaborate with first-movers to maintain a presence in the market and be reactive to changes in EV demand by preparing a strong entry strategy for when the situation becomes favorable. For all automakers, PHEVs should be a necessary short-term option to ramp up sales using existing vehicle platforms, while containing costs. For OEMs investing on Fuel Cell vehicles, path dependency should be highly taken into consideration. Time to market becomes a crucial element for innovative technologies, and delaying investments and mass market entry too long could leave EV manufacturers the possibility to ramp up volumes and create barriers to entry in the alternative powertrain market. Under all scenarios however, market disrupters such as Tesla, Apple or Google must be closely monitored as representing the highest threat for the incumbent industry players.

As a final remark, as has be done by some EV early entrants, companies wishing to seriously market electrified powertrain vehicles should heavily invest on debunking the myths (driving performance, safety, range, ugly design etc.) which are currently limiting EV adoption by uninformed drivers in order to gain volumes necessary to profit from these new technologies. Moreover, firms committing to a given technology should try to force its evolutionary path by heavily lobbying and collaborating to gain a strong commitment by complement asset producers in such a way to create the self-reinforcing mechanism, which eventually leads to the supremacy of the technology with the highest relative advantage, closing the doors for investments in alternative technological designs. Automakers should also be aware of profitable ICE manufacturers which have the potential to continue lobbying against emission standards, despite their investments and announcements in favor of emission “free” vehicles.

Future studies and developments

A first element which should be followed closely due to its direct impact on EV diffusion and industry evolution is Tesla’s Model 3 launch. A successful launch could mean the entrance of alternative powertrains in the mainstream market, the proof that the automotive market has the potential to be disrupted by newcomers, the success of direct marketing and the customer-centric approach, the importance of vertical integration and partnerships with critical component manufacturers, the need to focus on driver experience and software quality and most importantly the need for incumbents to re-visit their product portfolio and future competitive strategies.

Furthermore, the expansion of charging infrastructures, battery pack prices and the relating EV profitability and actual EV demand against forecasts should be monitored to update the 2021 projections and the relating entry strategies. Particularly important on this side will be the result of the diesel “defeat device” investigations which could further spur investments on the alternative technologies in an attempt to clean the automakers’ corporate image.

Limited attention has been dedicated to the Fuel Cell powertrain due to its limited potential impact in the period covered. Future developments could lead to the rise or death of the technology and should be hence monitored closely in the next few years.

Further research on the fields of autonomous mobility, new business models, vehicle connectivity, mobility as a service and their interaction with EV diffusion could further expand the base of knowledge of an industry in rapid evolution.

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Appendix:

2016-US	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Tesla Model S*	850	1,550	3,990	800	1,200	3,700	1,954	2,852	4,350	700	1,100	5,850	28,896
Chevrolet Volt	996	1,126	1,865	1,983	1,901	1,937	2,406	2,081	2,031	2,191	2,531	3,691	24,739
Tesla Model X*	270	270	1,860	795	1,600	2,145	750	1,833	3,200	725	900	3,875	18,223
Ford Fusion Energi	581	932	1,238	1,331	1,453	1,700	1,341	1,422	1,652	1,372	1,817	1,099	15,938
Nissan LEAF	755	930	1,246	787	979	1,096	1,063	1,066	1,316	1,412	1,457	1,899	14,006
Ford C-Max Energi	350	490	610	607	538	630	755	707	689	571	721	1,289	7,957
BMW i3	182	248	332	814	696	608	1,479	1,013	391	442	629	791	7,625
BMW X5 xDrive40e	181	345	313	655	500	583	649	876	482	406	436	569	5,995
Fiat 500e**	305	210	455	395	425	280	225	360	690	745	590	650	5,330
Audi A3 Sprtbk e-tron	327	243	332	326	361	353	349	346	312	348	394	589	4,280
VW e-Golf	328	198	86	326	269	248	344	454	529	407	305	443	3,937
Hyundai Sonata PHV**	175	200	275	250	235	225	375	235	260	255	285	325	3,095
Chevrolet Spark EV	139	216	252	419	394	359	333	292	315	260	39	17	3,035
Toyota Prius Prime											781	1,641	2,422
Porsche Cayenne S-E	146	172	244	237	191	176	148	197	131	138	179	152	2,111
Volvo XC90	226	176	178	150	110	166	178	176	148	142	161	204	2,015
Kia Soul EV	81	60	79	139	120	134	179	153	217	190	179	197	1,728
BMW i8	32	54	89	130	146	169	166	145	158	199	173	133	1,594
Ford Focus Electric	66	81	110	81	54	54	58	75	82	73	66	101	901
BMW 330e	0	0	19	25	67	26	81	51	54	92	215	240	870
smart ED	48	54	70	66	75	53	62	55	44	43	47	40	657
Mercedes B250e	58	37	66	56	49	44	50	57	51	58	52	54	632
Chevrolet Bolt EV												579	579
Mercedes S550H PHV	19	36	12	29	27	27	32	30	41	174	52	71	550
Cadillac ELR	67	91	104	95	45	94	15	6	6	3	5	3	534
Porsche Panamera S-E	27	33	23	25	26	22	21	59	28	38	88	3	393
Mercedes GLE 550e						19	30	24	26	19	30	83	231
Mercedes C350e												171	171
Mitsubishi i-MiEV	2	5	1	6	2	4	20	25	17	4	5	3	94
Toyota Prius PHV	10	6	7	4	4	11	4	2	4	0	0	0	52
BMW 740e												23	23
Other *	0	0	1	0	0	0	0	0	0	0	0	0	1

2017-US	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Chevrolet Volt	1,611	1,820	2,132	1,807									7,370
Tesla Model S*	900	1,750	3,450	1,125									7,225
Toyota Prius Prime	1,366	1,362	1,618	1,819									6,165
Tesla Model X*	750	800	2,750	715									5,015
Chevrolet Bolt EV	1,162	952	978	1,292									4,384
Nissan LEAF	772	1,037	1,478	1,063									4,350
Ford Fusion Energi	606	837	1,002	905									3,350
Ford C-Max Energi	473	639	662	749									2,523
Fiat 500e**	752	590	411	441									2,194
BMW i3	382	318	703	516									1,919
Audi A3 Sprtbk e-tron	387	400	414	301									1,502
VW e-Golf	332	293	342	307									1,274
BMW X5 xDrive40e	262	275	397	291									1,225
Hyundai Sonata PHV**	190	175	295	280									940
BMW 330e	129	144	365	260									898
Ford Focus Electric	56	228	407	120									811
Porsche Cayenne S-E	177	121	126	185									609
Kia Soul EV	117	152	171	167									607
Volvo XC90	96	83	103	145									427
Mercedes C350e	210	51	17	3									281
Mercedes S550e	55	51	60	81									247
Kia Optima PHV	10	61	70	86									227
Mercedes B250e	53	56	50	66									225
BMW 740e	18	35	42	123									218
Chrysler Pacifica Hybrid**	12	0	0	205									217
Mercedes GLE 550e	52	59	47	36									194
BMW i8	50	58	49	23									180
smart ED	15	22	13	3									53
Hyundai IONIQ Electric				19									19
Chevrolet Spark EV	4	4	3	1									12
Cadillac ELR	3	0	2	7									12
Porsche Panamera S-E	2	1	3	2									8
Mitsubishi i-MiEV	0	1	3	2									6
Cadillac CT6 PHV				6									6
BMW 530e				Arrives									
Porsche Panamera 4 E-H					Arrives								

Figures 24 & 25, US EV sales by model for years 2016 and 2017, source: Insideevs.com.

Summary

Introduction

Recent developments in regulatory emission standards in the hope of restraining the threat of global warming, turbulence in oil prices, technology innovation and especially, enhanced consumer and government interest in the green economy have brought to a reviving interest in alternative powertrain[392] technologies. More precisely, after a long dormant period, current environmental concerns coupled with the search for sustainability, and most importantly the rise of new players which have boldly heavily invested in the booming "0" emission automotive sub-industry, have awakened incumbents, most of which showed a lagging situation in the electrified powertrain technology knowledge and commercialization. In front of the contingence of being disrupted by new entrants or established competitors in an evolving market with strong growth potential, incumbents are being faced with a set of contrasting strategic decisions, which will determine their competitive future path. In this context, automakers with a constrained budget have to make decisions on which technology to invest on, which to develop commercially, when to go to market and in which manner. Collaboration strategies must also be taken into consideration when analyzing entry strategies as they entail the risk of losing precious proprietary technologies and knowledge on one side, but reduce the research and development time and costs in an uncertain environment on the other side.

Hence strategic decisions will have strong implications for the future evolution of the industry and its players given technology's strong path dependence caused by the self-reinforcing mechanisms which are characteristic of innovations distinguished by network externalities.

This thesis then, studies the main drivers of technological innovation for automotive powertrains, and more precisely the strategic decisions concerning investments, timing, mode and scope of entry and collaborations in the EV market. The aim of the thesis is to add to the knowledge of strategic management of technological innovations in the field of electrified powertrains, mostly focusing on Electric

[392] The main components that generate power and transmit it to the road surface.

Vehicles[393]. Moreover, as time and commitment seem to be the greatest discriminants in innovation management and relating strategies, an in depth analysis of the greatest[394] established automakers' entry strategies has been made. In particular, through the study of publicly available data, corporate master plans and specialized reports; time of entry, segments covered, models per segment and amounts invested have been analyzed to determine what will the main investment trends be for the period 2017-2021, year in which the EU emission regulations enter into force. By defining investment strategies based on both a dynamic and situational analysis, recommendations have then been made for automakers with a given current situation, wishing to gain a precise competitive position in the next few years. Following the discriminant of time, short, medium and long term projections have then been made regarding the industry's evolution to explain the possible behavior adopted by certain industry players which seem not to be following the trend of powertrain electrification.

To complete the analysis, the situation and strategies of new players, the influence of other innovative technologies over EV adoption and the conditions under which the diffusion of alternative powertrains will really benefit society have also been briefly studied.

Management of Technological Innovations

In industries characterized by high dynamism and dependent on technological products, innovation is the key element to maintain a competitive advantage and above average profitability. In technology-intensive industries then, having a well-established technological innovation strategy that helps to decide which innovations to invest on, when to invest and how to access them becomes of crucial importance due to the uncertainty and capital expenditure which characterize the innovation process.

When outlining their strategy, firms must also take into consideration the different sources of innovations. The main distinction can be made between internal and external sources, where the first imply an in-house employee driven R&D effort, while

[393] With greater attention reserved to battery powered electric vehicles over fuel cell electric vehicles.
[394] By volume and market capitalization.

the latter imply the whole net of connections which may arise between the firm and its external environment. The main balancing factors between the two sources of innovation retrieval are the need to have an internal R&D department with the ability of creating long-term competitive innovations, and the high costs and inefficiencies that internal departments may entail. The main distinctions which may be made for innovation types are by product or process, radical or incremental, competence enhancing or competence destroying and component or architectural. Due to the complexities inherent in technological innovations, such as those underlining electrified powertrains, the innovative dimensions tend to overlap making it difficult to characterize a technology under one simple dimension. It is worthy of notice how managing to develop an innovative competitive technology never is a guarantee of economic success. In fact, developing a technology for which there is no market will lead to poor financial returns.

During the development phase most technological innovations follow an S-curve evolution with respect to the amount invested per unit of time. This is mainly caused by the limited attention and funds which are reserved to technologies in their initial phase. As soon as they establish a certain degree of legitimacy and understanding, the increased attention by the scientific community and investors leads to a booming phase, where the technology's performance improves much faster per $ invested. Finally, once reached the maturity phase, every marginal improvement will need huge R&D investments. This is particularly important in the field of automotive powertrains, where ICEVs[395] have almost reached their improvement limit leaving space for disruptive technologies to enter the market. Disruptive technologies are particularly interesting, since they are usually brought forth by new entrants and pose incumbents in the difficult position of having to decide whether to invest on and market the new disruptive technology with the risk of losing market share and profitability in the current market, or follow a wait-and-see strategy, in order to see whether the new technology will really disrupt the market, while maintaining the established profit levels. Waiting too much, or failing to notice the importance of a disruptive technology, may then pose incumbents under the threat of being forced out of the

[395] Internal combustion engine vehicles.

market as the new superior technology becomes mainstream. However, as is happening in the automotive industry, a study by Bergek et al. (2013), discovered how in many industries, incumbents have “the capacity to perceive the potential of new technologies and integrate them with existing capabilities”, greatly reducing the risk of being disrupted.

Particularly important for the strategic decisions relating to timing and investments in innovative technologies are the innovation diffusion S-curves, which describe the spread of a technology through a population by graphing the cumulative number of adopters over time. The S curve is mainly due to the fact that the population is initially unfamiliar and unconscious about the technology which might be still immature leading to low adoption levels. However, as knowledge spreads due to internal and external communication channels and the innovation improves, diffusion speeds up as the product is adopted by the mass market and finally slows down as the market is saturated. The importance of studying the shape of diffusion curves relies in the fact that even if a new technology may offer greater performance and a greater potential market respect to the existing one a wrong timing or mode of entry may lead to a market failure. In fact, firms should delay investments if there is a lack of sufficient complementary resources or if customer education is low which would imply a low rate of adoption and low ROI in the first period with the risk of bankruptcy for companies lacking financial stability[396]. Also, identifying the technology’s point on the curve may give incumbents the possibility to “milk the cash cow” of current products as long as possible before turning to the new technology without the risk of finding barriers to entry. However, even though diffusion models such as those by Rogers, Utterbach or Bass do provide useful insights at an aggregate level, the application of the model for managerial planning does have some strong limitations. This is due to different considerations such as the rise of self-fulfilling prophecies where less funds are devoted to projects showing a lower diffusion potential or the complexities surrounding the new evolution of technologies once considered mature. This effect can hardly be predicted in advance when taking a managerial decision based on an S-curve.

[396] Such as startups, or firms which heavily fund their R&D expenses through Debt.

As innovations move through their technological cycle, they inevitably end up adapting to a dominant design responding to the mass market needs. In this situation, we can see how innovations are extremely path-dependent. This is mainly caused by increasing returns to adoption, incremental improvements, complementary assets and enabling technology development, production and design efficiencies which all lead to the the rise of a dominant design creating a self-reinforcing mechanism which will ultimately create a de-facto standard and bring to the elimination of alternative technologies. In this context, first-mover advantages become of crucial importance and create the incentives to enter the market early. Coalitions may be important to influence the selection of a preferred technology. This last consideration highlights the importance of collaboration strategies in the management of innovations, which coupled with a right timing and mode of entry, and marketing strategy can make the difference between controlling the dominant design or being left behind.

Particularly important for technology diffusion is the network externality effect by which the value of an innovation may be calculated by the perceived value of all the components of its system[397]. This strongly impacts the EV market as complementary assets such as the charging infrastructure, incentives to adopt the vehicles and to invest on them, and the perceived value of the new system with respect to the established one are all dependent on the number of users adopting the technology. In such a system, companies willing to postpone the introduction of new technologies may play on advertising their future superior product or on condemning the current lack of infrastructure, which would both have a similar result on current adoption.

After taking into consideration all these issues, the firm's main concerns in the innovation management process regard the strategic decisions of timing, investment and entry strategy alignment. With regard to timing, a right alignment is related to performance with early entrants featuring a broader, less selective innovation portfolio and late movers featuring a narrower, more selective portfolio. The first portfolio tries to cover high failure rates, while the latter tries to target a specific market need, since the failure risk has diminished. The main difference can be found in

[397] The stand-alone, the installed base, and the complementary assets value.

the level of market uncertainty and the risk profile of the strategy, with the first aiming at obtaining a temporary monopoly with a higher degree of risk, and the second aiming for more certain cash flows with lower rewards due to competitive preemption. However, early entrance also comes with a high portion of risk, since the future adoption will depend not only on the products' perceived quality, but also on the availability of complementary assets, and the presence of a large user base. The absence of any one of these components could lead to a failed diffusion and the rise of an alternative technology. The main strategic considerations will then be made on the net effect of first mover advantages vs. first mover disadvantages. Where the first may be mainly summarized in brand loyalty and technological leadership, preemption of scarce assets, buyer switching costs, and production scale and increasing return advantages, and the latter are mainly first-mover costs, immature enabling technologies or missing complementary assets and uncertainty of customer needs and requirements. In industries characterized by high dynamism and limited windows of opportunity what is really crucial then is the capacity of having the right competencies at the right time, in order for incumbent firms to maintain their established competitive advantage by entering the market when it is most attractive. Connected to the decision of which is the right time to enter a market is that of whether to do so alone or with partners. Firms have four ways to develop the necessary capabilities in order to enter new markets which are internal development, acquisitions, market transactions and alliances. The first three imply a solo strategy, while the last a collaborative strategy. The main reasons for going solo are the availability of necessary capabilities, and the risk of losing proprietary technology. The main reasons to collaborate are time concerns, a limited availability of funds, the need to access specific knowledge from partners, and the desire to establish a dominant design and a competitive advantage over competitors. A main deterrent to collaborations is however, the high difficulty in managing partnerships and the risk of one-side exploitation.

Summing up the different pros and cons of timing and entry strategies, it may be seen how the strategic decision will ultimately depend on the specific situation the firm is in, on its industry characteristics, and on different goals each company wishes to pursue.

2 The EV Market, Technologies and Investment Strategies.

"After power generation, road transport is the second biggest source of greenhouse gas emissions in the EU. It contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas"[398]. Reaching both energy sustainability and climate protection requires a transition from a petroleum-based transportation system to one dependent on a mix of electricity, hydrogen and biofuels. Governments are starting to take action in an attempt to start this energetic revolution, such as the EU which managed to set a mandatory reduction target for all new cars produced by OEMs for 2021. By that year, fleet average CO_2 emissions have to decrease from the actual 130gr per km to 95gr per km in order not to incur in a EU penalty. To improve efficiency car makers must invest in lowering their average fleet mass emissions and promoting their alternative fuel vehicles, which could considerably cut their weighted average emission levels.

Due to the continuously increasing improvement costs, the ICE powertrains are expected to lose market share progressively with respect to alternative propulsion variants. In fact, the year 2016 saw the global threshold of 2 million electric cars on the road, with an annual record of 774 thousand units sold. Put into perspective, this is a huge number compared with the few thousands of 2010. The main markets accounting for more than 80% of annual sales are China, US, Norway, Netherlands and Japan, with the first two weighing the most in terms of sales. The increased sales however only represent a market share of 0,86% globally entailing a high uncertainty over the future development of the automotive industry. However, the market is showing the first signals of a need that will ultimately result in a huge industry change brought by an inevitable disruptive innovation. Which innovative powertrain to invest on and when becomes the main concern for automakers which have to rely on EV market forecasts

[398] European Commission Press Release Database.

in order to make a correct timing and entry decision. Forecasts however, show great variance with projections differing widely based on strong, moderate and weak government policies, with 2035 market shares varying from 85 to 17%.

The main powertrains automakers may choose to invest on as of today are : ICE, HEV, REEV, PHEV, EV and FCEV[399], with the main differences being the propulsion system and the energy generation source. Car manufacturers then have a wide array of options on which to invest and from which to market, with BEVs presenting characteristics more suitable to short range travelling, and FCEV with characteristics more suitable to long-range trips. As of today, the TCO gap between ICE and EV of comparable models ranges from €5000 to €20000 with the lion's share of the price imbalance accruing to current battery prices. This situation is destined to improve as economies of scale build up, technology advances, supply chain matures and battery cost diminishes. Despite the promising future development of battery packs, the present competitiveness of cheaper ICE models translates in a lack of profitability for most EVs.

Automakers wishing to market electric vehicles must understand which are the main variables affecting their diffusion and adoption. It was found how, following Rogers' model, these were several, but can be mainly summarized by: the EVs' "0" emission, high torque and performance potential, the charging infrastructure availability and charging time, the battery driving range and cost, the difference in purchase price, the cost of fuel, the model availability and durability, the compatibility with driver's current values and habits, the complexity to adapt to the new system, the easiness with which the new cars may be tested, and the observability of the benefits of EVs to the general public. These variables must be weighted to determine a buyer's propensity of adoption. However, given the higher importance of price and driving range on the other factors, government incentives and battery improvements seem to be crucial to boost the initial product diffusion. From the supply side instead, vehicle profitability will be one of the major drivers to investment and product

[399] Internal combustion engine, hybrid electric vehicle, plug-in hybrid electric vehicle, electric vehicle and fuel cell electric vehicle, without considering other bio-fuel powered vehicles.

commercialization, making battery pack prices and customer willingness to pay the major determinants of product diffusion.

To complete the above analysis, when considering EV market entry strategies, 4 main structures have been analyzed and adapted to the current industry's situation: the scope of investments for the 2017-2021 period, the EV market entry timing, the entry strategies based on production capacity and R&D expenses, and lastly the strategies brought forth by new market entrants. The first analyzes automaker's entry strategy based on the number of segments covered and the number of models offered per segment, and gives a picture of the evolution of automakers' situation in the next four years. The second instead analyzes market entry timing based on each automaker's mean EV asset position and its mean annual income in the ICE segment prior to the commercialization phase, in such a way to determine how entry strategies are influenced by early entrant and late entrant incentives. The third model analyzes market entry timing based on established OEMs' current R&D investments and their manufacturing capability, in such a way to discriminate incentives based on the automakers' production power and their present and future invested stakes in the technology.

Company data and external reports have then been used to classify established automakers and some new players according to the given models in such a way to determine trends in investment and entry strategies. Automaker commitment was also analyzed from a non-market perspective, by looking at their presence in the EV sport and military industries. F-Cell technology investments were found to be a major explanatory variable as for why some big automakers have a small presence in the battery powered market. Automakers were also found to be relying more on collaboration strategies on this technology due to its higher risk due to the small current market and the need to push it as an alternative dominant design.

Finally, the strategy of small players and EV startups was found to be similar inasmuch their limited funds availability and production capacity, summed up to their smaller model portfolio implies that their main goal will be that of market segmentation. A few (in most cases just one) premium models will be commercialized by these companies which will target wealthy car owners searching for unique designs or alternative products. Their impact on the car industry will mostly be that of elevating the image of electric cars by demonstrating outstanding performance and strong personality, with little to no influence on industry EV market share for the period 2017-2021.

Conclusion

When talking about automotive powertrain innovation, the decisions of which technology to invest on, when to invest and how to access it become particularly hard due to a series of factors such as technological and demand uncertainty which make forecasting strenuous and investments highly risky. Managing to assess correctly a market entry strategy involving both timing and entry volume, a collaboration strategy in order to minimize investments while maximizing technology learning and market share, and a correct technology strategy trying to predict what the future of powertrain mobility will look like will make a difference in the medium-to-long term competitive position for established and new-entrant automakers. A disruptive innovation such as the electrification of the automotive powertrain has then the potential to re-shape the current industry equilibrium with the possibility of seeing the surge of new dominant players in this “old” established market. This is particularly true if we consider electrification as a competence destroying innovation which will render ICEs obsolete with time. However, all established automakers have the funds and time to eventually gain a sufficient knowledge base also in these new technologies.

In this context two powertrain technologies have been studied, hydrogen fuel-cell and battery electric, with most of the focus falling on the latter due to the short-term scope of the analysis. More precisely, the first represents a technology, which is being studied and developed by a restricted number of players, entailing high investment risks, but high returns if the said automakers manage to make fuel cells mainstream. The latter instead represents in comparison, a lower risk and lower reward technology, due to the great number of players following that innovation path, which however has the potential to set itself as the dominant design, cutting out competing “0” emission technologies from the market. Automaker individual innovation strategies have then been analyzed to find investment trends based on a company’s current situation and pursued objective. For the period 2017-2021, year in which the EU emission regulations will be implemented, established automaker's past, present and stated future behavior regarding investment amount and timing, technological choice and inter and intra-industry collaboration have been analyzed to determine the evolution of and the entry strategies specific to the EV market.

In particular, after having acknowledged what are the demand forecasts for the period according to the most recent reports, and what are the predicted 2021 automaker emission with the related possible fines, defining thus, what are the industry-wide EV influencing variables, an in-depth analysis of single automaker's corporate strategy regarding electrified powertrain innovation has been conducted. Keeping in mind the pros & cons of each technological powertrain and the influence of the most recent developments on the different technological paths, entry strategies for the period under analysis have been defined according to the following variables: automaker portfolio's segments covered by EVs and models per segment, automaker's manufacturing capability and R&D spending and expected investments in powertrain electrification, and past and present standardized EV asset position and mean net income as indicators of investment incentives.

It was found that for the 2021 period, no established automaker will commit completely to the new disruptive technology due to a number of factors such as demand uncertainty, ICE profitability, insufficiency of complementary assets and enabling technologies (which impact via the network externality effect) and mostly unwillingness to in customer education due to free-riding, but will be mostly playing a wait-and-see strategy preparing to enter strongly as soon as the situation becomes more favorable. Until EVs do not become sufficiently profitable then, established OEMs will continue milking the "cash cow" while simultaneously slowly developing the alternative market. Market presence will then be mostly pursued for production scale, exclusive supplying contracts and the creation of a strong brand presence. It becomes evident then, how the automotive industry applies to the case brought by Abell (1978), for what is really crucial in such a technology-intensive industry is the capacity of established automakers to have the right competencies at the right time, in order to maintain their competitive advantage in a continuously evolving environment.

As regards portfolio model strategy, most big automakers will follow a trial diversification strategy launching single models in multiple segments such as Daimler, BMW, VW and partly Nissan-Renault. For most automakers in this grouping, the applied strategy represents a continuum with that currently adopted for ICE vehicles[400]. Tesla on the other hand is pursuing such a strategy due to its newness to the automotive market and the technological-product lifecycle path it is following. Other automakers such as Hyundai, Kia and Ford are instead following a specialization strategy, pursuing a mass market entry in a single or few market segments in an attempt to build a strong market share and establish a barrier to entry on late-followers. Qualifying competitors instead will only launch a few models in one or two segments due a late market entry strategy such as Toyota and Honda, a limited technological asset position such as PSA, or a limited vehicle portfolio such as Volvo or Jaguar. GM also belongs to this group as it has concentrated most of its efforts on the launch of one mass market EV, pursuing a high, market risk-reward strategy. A number of players such as FCA, Suzuki and Mazda show a limited to no interest in entering the EV market thanks to their current low emission's position and will probably act as late entrants.

For what regards entry timing instead R&D efforts, manufacturing capability and incentives to innovate represent the fundamental variables. In particular companies showing a strong EV asset position and a lower than average ICE net income have strong incentives to be early entrants in the EV market in the hope of re-shaping the industry and their competitive position. Adding to the current technological knowledge position, manufacturing capability strongly influences entry timing as companies with a lower capability will need to enter early and build market share in order to compete with group's presenting larger and more effective production capacities. In this respect we may see how BMW, Daimler and Tesla have the right incentives to become early entrants, while the Nissan-Renault group has both the incentives to enter early and the manufacturing capacity become an early follower. Groups with mixed incentives and technological asset positions such as VW, GM, and Hyundai/Kia will follow early entrant or fast follower strategies mainly based on their current EV market situation.

[400] The mission of becoming the best in all segments entered.

Toyota and Honda instead, which have little incentives to go to market, but high manufacturing and technological capacities will act as late followers, monitoring the market for the best entry situation. Finally, some automakers such as FCA, PSA, Suzuki and Mazda will have to follow a laggard strategy due to an insufficient technological position and will tend to focus on future market segmentation or cost minimization based on their manufacturing and productive capacities. Smaller automaker groups will also have to act as followers, mostly following a market segmentation strategy as they lack the resources to educate the market and aggressively introduce vehicles with an uncertain demand.

New players mostly represent sports-car or supercar manufacturers which are following an early entry market segmentation strategy by marketing to a small set of EV wealthy lead users.

The entry strategy pursued by most if not all established automakers at present in the BEV segment is that of internal development (with the aid of external information, obtained through collaborations or external hiring) given the widespread technological knowledge, the lower level of investment risk, the need to create a long-term competitive advantage, and the industry's history of developing fundamental technologies in-house. Moreover, the requirement of designing and developing new powertrains internally comes from automaker's need of developing products which are consistent with the corporate design and culture. On the contrary, collaboration strategies in innovation seem to be proportionately dependent to the risk involved & the current technological knowledge base, and inversely dependent to the cash availability & the need to create a competitive advantage over the technology. This translates in a frequent recourse to partnerships and alliances in the field of charging infrastructures which display a low competitive advantage potential, in fuel cell technologies, which entail high investment risks and for which budgets are presently limited, and among automakers and battery suppliers, in an attempt to create a long-term competitive advantage through exclusive supplying contracts. On the contrary, established automakers have stopped creating ad hoc partnerships for EV development in an attempt to build proprietary technology and knowledge and increase their absorptive capacity. Joint Ventures are still fundamental to access certain developing markets and are still particularly strong in China, with new partnerships being formed at present. If in the past alliances were formed in the BEV segment due to lacking technological knowledge, today the need to create a competitive in-house knowledge base requires going solo on marketable technologies.

In launching EVs established automakers will concentrate their efforts at first on the 3 big markets, China, USA and Europe necessary to gain the required sales volumes to justify production. Moreover, a distinction will be made in the single regions depending on Government incentives, existing charging infrastructures and customer attitudes towards battery powered vehicles. Developed dense cities with stricter emission regulations will show a higher rate of adoption, with sales penetration being lower in rural areas and small towns due to longer driving ranges and lower incentives.

Apart from the previous factors, important influences on the evolution of each automaker's corporate innovation strategy have been the current surge in emission scandals with the related PR and economic damage, changing Government directives concerning emission standards and the evolution of enabling and complement technologies, which continuously change the environment in which the companies compete.

Recommendations

Automotive companies cannot forecast future industry developments with certainty, they can however build strategic plans to prepare for disruption and be ahead of competition by taking steps to shape the evolution. To do so they will need to closely follow market trends regarding enabling technologies and business model evolutions. In an industry showing growing complexities partnerships and cooperation along the value chain will be needed to form competing ecosystems, especially when considering mobility as a service. To be ahead of competition, automakers must be at the avant-garde in all new potential mass technologies, comprising electrified powertrains, autonomous driving technologies and car connectivity. Considering entry strategies, automakers with a strong EV asset position which plan to heavily commercialize alternative powertrains in the 2017-2021 period in order to build market share and exploit first mover advantages should ramp up lobbying efforts on eco-friendly environmental policies. This is because, as seen in Chapters 2 and 3, most established automakers will manage to each 2021 emission targets without having to depend strongly on alternative powertrains. This means that expected cost reductions and efficiency improvements will only be reached with Government support. In particular, strict emission standards and both fiscal and non-fiscal incentives for EVs are needed to tip the balance towards electrification in the short to medium term, as electrified push strategies will only succeed if companies manage to reach certain volume thresholds. Also, innovative business models, such as car sharing services could be used to increase EV's time on road and reduce their TCO, increasing their relative advantage against ICE vehicles. If EV demand results being lower than forecasts, first-movers should try to form collaborations in order to create strong market positions, reputation branding and create industry standards in order to reduce investment risks. Automakers with strong EV asset positions but low incentives to market should instead keep building their EV asset position, collaborate with first-movers to maintain a presence in the market and be reactive to changes in EV demand by preparing a strong entry strategy for when the situation becomes favorable. For all automakers, PHEVs should be a necessary short-term option to ramp up sales using existing vehicle platforms, while containing costs. For OEMs investing on Fuel Cell vehicles, path dependency should be highly taken into consideration. Time to market becomes a crucial element for innovative technologies, and delaying investments and mass market entry too long could leave EV manufacturers the possibility to ramp up volumes and create barriers to entry in the alternative powertrain market. Under all scenarios however, market disrupters such as Tesla, Apple or Google must be closely monitored as representing the highest threat for the incumbent industry players.

As a final remark, as has be done by some EV early entrants, companies wishing to seriously market electrified powertrain vehicles should heavily invest on debunking the myths (driving performance, safety, range, ugly design etc.) which are currently limiting EV adoption by uninformed drivers in order to gain volumes necessary to profit from these new technologies. Moreover, firms committing to a given technology should try to force its evolutionary path by heavily lobbying and collaborating to gain a strong commitment by complement asset producers in such a way to create the self-reinforcing mechanism, which eventually leads to the supremacy of the technology with the highest relative advantage, closing the doors for investments in alternative technological designs. Automakers should also be aware of profitable ICE manufacturers which have the potential to continue lobbying against emission standards, despite their investments and announcements in favor of emission “free” vehicles.