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# ACHIEVING 2050 DECARBONISATION TARGET OF THE AUTOMOTIVE INDUSTRY IN EUROPE: A MULTI-LEVEL ANALYSIS

*Fatih M. Özel 1*

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The European Union (EU) aims to reduce overall $CO_2$ emissions at least 80% by 2050. For road transport, this involves at least a 95% reduction target for 2050, compared to 1990 levels. Most commentators argue that achieving this target requires a transition from internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). Nevertheless, this entails substantial changes in the automotive value chain, which will not be motivated by single factors. To support the automotive sector responding the aforementioned target, the factors limiting the new technology in the sector was analyzed and challenged by applying the socio-technical transition theory to the automotive system and examining the existing requirements of critical actors. It was found that a technical change might be possible with an industrial structure favoring the production and consumption of BEVs. However, to achieve that, BEV technologies that are developed in niches by established companies and new entrants need to be further developed and prescriptive policy instruments need to be implemented in a timely manner. Some helpful strategies were also identified and discussed for satisfying the needs of governments, carmakers and small and medium sized enterprises.

**Keywords:** *European automotive sector; 2050 $CO_2$ target; socio-technical transitions; battery electric vehicle; sustainable mobility*

## 1 Introduction

The Earth has experienced an altering climate since the beginning of time. However, during the last century, human activity has resulted in important climate change over a moderately short time period. The term “global warming” is well recognized in literature and describes the measured increase in the World’s average temperature. This is caused by the build-up of key greenhouse gases (GHG) in the atmosphere accumulated from incessant combustion of fossil fuels and land-use changes over the 20th century [1].

As a response, numerous governments have signed the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) that was held in Rio de Janeiro from 3 to 14 June 1992 [2] and they have agreed that global warming has to be limited to below 2°C compared to the average temperature in pre-industrial times to prevent the most severe impacts of climate change [3]. The Kyoto protocol, an international agreement under UNFCCC, was also adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005.

Since oil is the dominant fuel source for transportation with road transport accounting for 75% of total energy use by the transport sector, transport in particular road transport is a major contributor to GHG emissions [4]. For the European Union (EU), transport was responsible for approximately 25% of the GHG emissions in 2012. Road transport alone contributed nearly 20% of the EU's total emissions of $CO_2$, the main GHG [5]. The transport sector is also susceptible to oil supply disruption and price instability [6].

In response, and also to comply with its commitments under the Kyoto Protocol, the EU aims to reduce overall $CO_2$ emissions by 20% by 2020 and by at least 80% by 2050 [7]. For transport, this involves at least a 60% reduction target for 2050, compared to 1990 levels [8]. Achieving at least 80% decarbonisation overall by 2050 also translates into at least 95% decarbonisation of the road transport sector compared to 1990 levels [9]. Most commentators believe that achieving this target requires a transition from internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs) [10-16]. However, such transition is very challenging as it demands fundamental changes in the whole automotive value chain [17-26], which will not be motivated by single factors [22, 27, 28].

This paper aims to analyze factors limiting the technical transition from ICEV to BEV in the automotive sector in Europe and develop multifaceted strategies to challenge these factors in order to support the sector responding the 2050 $CO_2$ emission reduction challenge.

To this end this paper proceeds in the following fashion. In section two, consideration is given to technological alternatives and in particular to the need for a transition from ICEVs to BEVs for achieving 2050 decarbonisation target. In section three, socio-technical transition theory is discussed and applied to the automotive industry to understand and theoretically elaborate the critical factors and actors for achieving technical transition. Thereupon, existing significant challenges faced by these actors are examined in section four. In section 5, corresponding strategies are presented to overcome these challenges. Finally, in section 6, some brief conclusions are given with respect to the study undertaken.

## 2 Technological Alternatives to Reduce Carbon Emissions from Automobiles

The automotive industry is currently dominated by the ICEVs which use petroleum gasoline or diesel fuel with two types of engine: spark-ignition for gasoline, liquid petroleum gas and natural gas; and compression-ignition for diesel fuel. Diesel engines are thought to be approximately 25-30% more energy efficient [4]. However, ICEVs are largely inefficient since 14-30% of the energy contained in a litre of fuel is used to drive an ICEV depending on different driving conditions. The rest of the energy is lost to internal combustion engine (ICE) and driveline inefficiencies or used to power accessories [29].

A significant potential therefore exists for increasing the efficiency of ICEVs with overall vehicle improvements and ICE improvements. The EU`s 2050 target, which implies 95% decarbonisation of the road transport sector compared to 1990 levels [9], also translates into a $CO_2$ emission target of 10 $gCO_2$/km for the average of new cars sold by 2050 [30]. However, the lowest $CO_2$ rates that can be achieved with fossil fueled ICE powertrains are thought to be 80-90 $gCO_2$/km for the best diesel ICEVs. To increase the efficiency above this limit necessitates electrification and/or biofuels [31]. As there are concerns regarding the environmental impact of biofuels such as overall increase in the GHG emissions due to the production of biofuels and land use changes [32], most authors now express that electric propulsion or electric mobility represents the most viable short-term solution for the sustainability needs of automotive industry [10-16].

Electric propulsion is a technological alternative to the ICE. Vehicles that use the electric propulsion technologies are described as electric vehicles (EVs). Different types of EVs including hybrid vehicles (HEVs), plug-in hybrid vehicles (PHEVs), range-extended electric vehicles (REEVs), fuel cell electric vehicles (FCEVs) and BEVs have been recently designed with the aim of solving pollution problems caused by the emission of ICEV. The prefixes to "EV" recognize the differences in the primary propulsion, primary energy storage units and drive train configurations.

However, it is not possible to reduce emissions below 60 $gCO_2$/km with the best diesel hybrid vehicles [31]. This suggests that a gradual shift from ICEVs to BEVs and FCEVs with hybrid vehicles and REEVs as bridging technologies need to occur in the EU. Since it is thought that FCEVs will be mainly used for larger vehicles in road transportation while BEVs will be the main technological option for the automotive industry in 2050 to comply with the EU`s 2050 target [30], the rest of the paper will focus on a transition from ICEVs to BEVs for achieving the EU´s long-term $CO_2$ reduction target.

## 3 Transition Theory and Critical Factors for Achieving a Transition in the Automotive Industry

According to the innovation literature, electric propulsion technologies are radical technologies that have substantial impacts on carmakers and suppliers, infrastructure providers and consumers etc. [33-37]. Due to the multi-dimensional impacts of BEV technologies, a successful technology change involves overcoming barriers that go far beyond purely technological innovation; and that economic, business, infrastructural, institutional and societal innovations are just as important [17-26]. Hence, a transition from ICEVs to BEVs represents more than a technological challenge [22, 27, 38]. In fact, it is recognized as a "socio-technical" challenge [17-26] requiring co-evolution between multiple developments in the whole automotive value chain [22, 27, 28].

The multi-level perspective (MLP) on socio-technical transitions which describes the structure and dynamics of socio-technical systems is therefore frequently used in literature to understand and study technological transitions in road transport system [19, 22, 24, 28, 39-41]. The framework is called MLP as it identifies three analytical levels within socio-technical systems: niches, socio-technical regimes and an overarching socio-technical landscape. Niches form the micro-level in which radical EV innovations emerge. The socio-technical regime forms the meso-level, which comprises dominant institutions and ICEV technologies and, thus, accounts for the stability of existing automotive system. The macro-level is formed by the sociotechnical landscape which is an exogenous environment outside the direct influence of niche and regime actors and it represents trends, and contextual drivers and barriers to change [22].

In the MLP, linkages between elements at above discussed levels might initiate technological change and result in new regimes [28]. Even though each technology transition is distinctive, transitions are generally initiated by the interaction of developments at three analytical levels: (a) niche-innovations build up internal momentum (bottom-up), (b) changes in the overarching landscape level create pressure on the regime (top-down), and (c) destabilization of the regime creates windows of opportunity for niche-innovations [22]. As a result, old technology regime is replaced by the new radical technology and a transition is occurred.

When this theory is applied to the automotive system, it can be seen that the dominant ICE technology is very firmly embedded within society and the economy, and all of the actors and rules are geared towards this technology [42, 43]. The "ICEV regime" concept is used to describe such situation. According to Wells [18], at the core of this regime, there are carmakers and their technology packages of the all-steel body, the ICE and a distinctive business model built upon "centralized manufacturing economies of scale, long inbound and outbound logistics lines, franchised retailers, and the outright sale of cars (and associated finance) as the primary source of revenue". However, around this core, there are multidimensional "shell" of supportive commercial activities, social frameworks, practices, infrastructures, lobby groups, behaviors, culture and beliefs etc. that contribute to and mainly strengthen the existing ICEV regime.

Consequently, achieving a transition from ICEV to BEV requires a regime change which means significant changes in the whole automotive value chain. As such situation threatens established companies which have vested interests in the existing industrial structure, they innovate mostly incrementally by continuously improving ICE technology to defend their current positions and business models [25]. On average, around 80% of the automotive industry's patents are assumed to be awarded to ICEV related technology, against only about 20% for technologies associated with EVs [44].

As automobile manufacturers and other regime participants such as fuel providers and consumers typically resist the radical technology change, a transition from ICEV to BEV only comes about if there is a pressure from the landscape level on the ICEV regime which destabilizes current practices and creates opportunities for BEV technologies that are developed in niches to break through [18, 22, 24]. According to previous studies, such pressures could be climate change and related policy measures for BEVs [18, 25, 41, 45, 46].

Therefore, radical technologies are tend to firstly develop in niches [17, 18, 22, 47-49]. Niches fill several important functions such as shielding the radical technologies from competition [50-52], nurturing further development and assisting network building [52]. The protection for BEV technologies is significant as they fail to successfully compete within selection environments embodied in ICEV regime. Therefore, they need to be shielded against some of the dominant selection pressures and nurtured through performance improvements and expansions in supportive networks. However, the need for protection might decrease progressively as they develop and enter to more diverse markets. Typically, the protection for niches is provided with government policies. However, it may also be provided when private firms commit considerable R&D budgets to the development of particular innovations [50].

In niches, the innovations are largely developed by outsiders to the existing regime which are also known as new entrants or newcomers [53] since they have little to lose and no vested interests compared to incumbent companies [54]. Besides, radical innovations lower entry barriers and open up windows of opportunity for newcomers to enter the market [53-61]. In the case of the automotive industry, it can be said that, currently at least, technological innovations are rather layered on top of the existing regime rather than displacing it since existing carmakers are also developing BEV technologies owing to the increased stringency of GHG regulations.

Based on above mentioned theoretical constructs, an ideal-typical illustration of how the three levels interact in a dialectic manner in the unfolding of BEV socio-technical transition is illustrated in Figure 1. As can be seen, the following critical factors and actors can be identified for achieving a technical transition in the European Automotive Industry:

- *Socio-technical landscape level:* Policy measures support technical change by creating pressure on the regime participants as well as opening windows of opportunities for BEV innovations developed in niches. To facilitate the change, the right instruments need to be implemented at the right time by governments.
- *Socio-technical regime level:* The core of the ICEV regime is composed by carmakers with their value creation and capture activities. A transition to BEV regime requires fundamental changes in those activities. The exploitation and occupation of BEV related value-add activities by carmakers therefore accelerate the transition.
- *Niche level:* Technical developments pursued by established companies and new entrants support the technical change. However, protection by means of governmental policies is required to shield these technologies from competition, and nurture the development and dissemination of these novelties. For assisting the technical transformation, understanding and supporting the new entrants are therefore crucial.

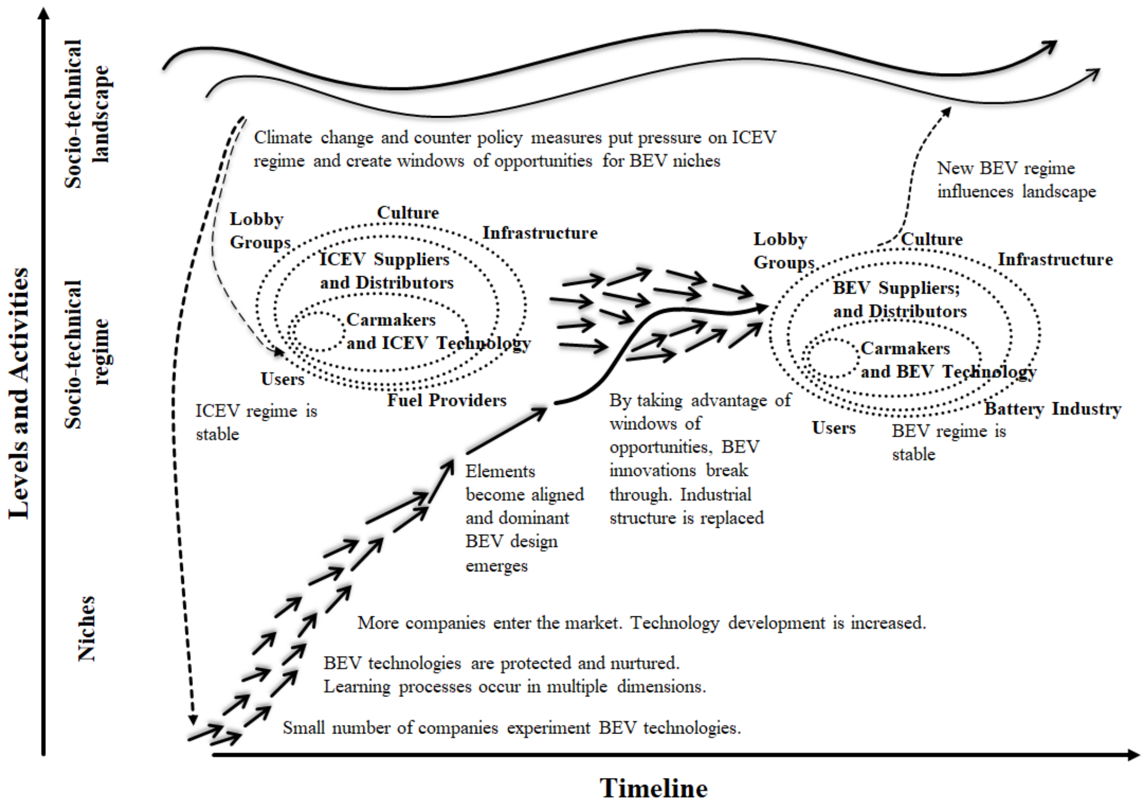


**Fig.1.** An illustration of socio-technical transition from ICEV to BEV based on MLP. Own illustration based on [22]

## 4 Existing Challenges Faced by Critical Actors

Based on above mentioned theoretical findings, the existing activities in different levels are explored and analyzed in the following sub-sections to articulate the challenges faced by critical actors involved in the BEV value chain in Europe.

### 4.1 Governments and Prescriptive Policy Instruments

As suggested by the transition theory, a technical transformation in the automotive industry is very unlikely to happen on its own within an acceptable period of time which ensures the EU`s 2050 road transport decarbonisation pathway. This is because ICEV based value chain is strongly invested. Vehicle manufacturers are still investing mostly to improve the ICEV efficiency [44, 58, 62-67]. The present market structure also benefits continuation of ICEVs and consumers are not yet familiar with BEVs. Besides, BEVs necessitate a considerable investment by consumers owing to the high sales price of BEVs compared to those of similar ICEVs [68]. This is mostly because of the additional cost of batteries [69, 70]. Additionally, BEVs create uncertainty for drivers owing to the limited range and long charging intervals. Thus, charging stations need to be established, battery performance need to be improved and range extenders or other related technologies need to be developed [68, 70]. While charging stations are established, issues such as interoperability, maintenance and the required time to charge need to be solved [68]. It is therefore increasingly recognized that prescriptive policy interventions are necessary to stimulate the development of BEV technologies.

Aligned with such perspective, most of the EU's countries have established supportive policies for the accelerated introduction of BEVs. An illustrative example of supportive policies is the 2009 National Development Plan for Electromobility in Germany, which set a target of 1 million BEVs in the national fleet by 2020 and provided €500m in funding support. German government aims to reduce the dependence on oil and decrease $CO_2$ emissions, and strengthen Germany as an industrial and technological location [71]. Although environmental targets exist too, industrial goals play a more significant role for German policies since Germany`s economy is highly dependent on its automotive industry and this is endangered by a global transition from ICEVs towards BEVs [41].

Another significant example is Norway, which has the highest EV market penetration rates in Europe. To reduce the carbon emissions in the road transport sector, the country has specified a $CO_2$ emissions target for new vehicles which is 85 g/km by 2020. However, since Norway has no car manufacturing industry, the country`s policies focus primarily on "user behavior, raising awareness, and charging infrastructure.

For example, Transnova (now Enova) received 50-100m Kroner (~€6-12m) between 2009 and 2010 to support the introduction of BEV technologies and to finance charging infrastructure for BEVs. In 2013, another 6m Kroner (~€720,000) were made available by Transnova to support the fast charging infrastructure. Transnova also funded "Grønn Bil" (green car), which aims to accelerate the uptake of EVs by publishing statistics on EV registrations and charging points [72]. Besides, BEV users have preferential access to a significant part of public infrastructure, including "free access to toll roads, reduced fares on ferries, free parking, access to bus lanes, and free charging at public charging" [73]. PHEV users are also allowed to charge for free at public charging stations in some cities. However, they must pay the standard parking fee. To facilitate the enforcement and increase the visibility of those measures, EVs have also received special "registration plates" using the prefix "EL" since 1999.

In terms of financial incentives in Norway, BEVs are exempted from the registration tax (until 2020). Although PHEVs are not exempted from the registration tax, they still gain lower registration taxes compared to ICEVs owing to lower $CO_2$ emission values. BEVs have also been exempted from the VAT, which usually adds 25% of a vehicle's list price to the total cost, since 2001. The VAT exemption is aimed to be continued until the end of 2017. The list price of BEVs is decreased by 50% in the calculation of the company car tax. This incentive is aimed to be continued until 2018 [72]. As a result of these supportive policies, at the end of 2015, there were approximately 75,000 BEVs and about 12,000 PHEVs registered in Norway. This represents a 17% market share for BEVs and 5% market share for PHEVs [74].

Other countries in the EU are also developing specific policy measures both to support technological development and to stimulate the market pertaining to BEVs based on national governments` specific BEV transition targets. However, as can be clearly seen in the case of Norway, there are several instruments which national governments might use. The appropriate selection and timely use of instruments is therefore highly significant. Currently, ex-post analysis is mostly used for assisting the selection of instruments. However, it is increasingly inadequate to the task of guiding the effective choice of policy interventions. To evaluate different policy measures and enable the ex-ante analysis of those measures, innovative frameworks are therefore required.

### 4.2 Carmakers and Value-Add Activities

To achieve the 2050 target, mass production of BEVs is required [75]. Nonetheless, this requires new technologies and new competences. For example, BEVs need new generations of batteries, electric motors and inverters while they do not require some of the vital technologies of ICEVs such as ICE and gearboxes. Besides, new forms of thermos-management need to be developed since there is no longer a combustion process generating heat which can be used for heating or cooling. Thus, a significant part of the automotive architecture needs to be redesigned [70]. This means that there will be a considerable change in the value-add creation for carmakers. Whereas there would be a loss of value-add associated with the ICE and gearbox as well as additional components which correlate with a design optimized on an ICE, there would be additional value-add tied to the BEV component costs.

The BEV drivetrain represents the 60% of the total value add, and nearly 85% of the value add of the BEV drivetrain is attributable to the battery. Overall, the total value-add would be far higher for the BEV – by approximately 63%. However, the move from ICEV to BEV could represent a significant loss in value-add from the point of view of the carmaker – circa 75% of the present value added by the powertrain. Therefore, carmakers need to re-evaluate their make-or-buy decisions, especially with regards to powertrain technologies and batteries [76].

Some established carmakers as well as new entrants have already started investing heavily for capturing BEV related value-add activities. This can be identified by examining the EV sales. In 2015, the number of cars sold worldwide reached approximately 89 million units. Total global EV sales were also close to 2 million [77]. In 2016 (January-May period), worldwide EV sales hit around 240,000. The best seller was Nissan Leaf followed by Tesla Model S (new entrant). Another new entrant`s (BYD) three models also appeared in the world`s top 10 selling plug-in cars. In terms of automobile manufacturers, BYD was the largest plug-in automobile manufacturer with over 33,000 deliveries. Since BYD`s PHEVs and BEVs are available only in China, BYD`s success is noteworthy. Nissan with global presence of LEAF is second at nearly 24,500 with Tesla on the tail, approaching 22,000. Other largest plug-in automobile manufacturers were BMW, Mitsubishi, Volkswagen, Renault, BAIC, Chevrolet and Ford respectively [78].

Owing to its high value-add, several firms from very diverse sectors have started to invest in lithium-ion batteries, which are used commonly for the on-board energy supply of BEVs [79, 80]. For example, in addition to the established battery companies, such as Bosch, Varta and Johnson Controls, chemical companies, carmakers (often in joint ventures with prominent battery producers from Japan and Korea), automotive parts manufacturers as well as plant engineering and construction firms are increasingly entering into the battery value chain. Tesla´s Gigafactory also started to produce batteries at the beginning of 2017 and it is expected to reach full capacity in 2020, and produce more lithium-ion batteries annually than were produced worldwide in 2013 [81].

**Table 1:** World`s Top 10 Battery Makers Ranked by MWh Produced in 2015. Compiled from [82]

| Battery Producers | 2015 (MWh) | 2014 (MWh) | %` 2015 | %` 2014 |
|---|---|---|---|---|
| Panasonic | 4552 | 2726 | 38 | 38 |
| BYD | 1652 | 461 | 14 | 6 |
| LG Chem | 1432 | 886 | 12 | 12 |
| AESC | 1272 | 1620 | 11 | 23 |
| Mitsubishi/GS Yuasa | 600 | 451 | 5 | 6 |
| Samsung | 504 | 314 | 4 | 4 |
| Epower | 489 | N/A | 4 | N/A |
| Beijing Pride Power (BPP) | 397 | 121 | 3 | 2 |
| Air Lithium (Lyoyang) | 283 | N/A | 2 | N/A |
| Wanxiang | 268 | N/A | 2 | N/A |
| **TOTAL** | **12289** | **7167** | | |

This trend can be recognized by examining the production numbers. For example, production grew around 72% in 2015 compared to 2014 as displayed in Table 1. Panasonic was the leader in terms of battery production with 38% of market share in 2015. A significant part of Panasonic batteries have been used in Tesla Model S. However, the Chinese company BYD which was the second in the top 10 battery makers list grew even faster. The South Korean manufacturer LG Chem was the third in the list. However, AESC (Automotive Energy Supply Corporation) which is the joint venture between NEC and Nissan lost 12% market share in 2015 compared to 2014. Although Lithium Energy Japan`s (GS Yuasa / Mitsubishi) sales increased, the company lost 1% market share. Samsung which has a partnership with BMW and FIAT also increased the battery production.

There are also other ongoing activities to occupy BEV related value-add activities. For example, battery producers have started manufacturing cars such as BYD in China and Bolloré in France; tyre manufacturers such as Continental and Michelin produce entire concept cars; chemical companies such as Evonik increase their auto parts portfolio; and carmakers and energy utilities venture into new mobility services, such as car-sharing.

In short, a technical transition in the automotive industry requires considerable changes in the value-add creation for carmakers. Some new entrants (i.e. BYD and Tesla) have already started occupying high value-add fields and challenging the established companies. The battery production is dominated by Asian companies. To take advantage of the paradigm changes in the industry, new business models are also emerging. Although the European Automotive Industry is strong, European Carmakers need to consider their make or buy decisions and invest more in the high value-add activities, especially in the battery value chain, and exploit and use new game-changing innovative business models.

### 4.3 Newcomers and Measures to Support Them

As suggested by the transition theory, established companies typically have vested interests and they are inclined to defend their current positions and business models with incremental innovations rather than fully adopting radical innovations. Such situation also explains the ICEV focused strategy of many carmakers. On the contrary, new entrants are much less constrained by dominant institutions and the status quo [25]. Thus, new entrants are recognized as more capable of developing radical technologies in literature, especially when technologies are still in the “niche” status.

New entrants include both micro, small and medium sized enterprises (SMEs) and diversifying established firms moving into emerging BEV markets [53]. Yet, recent studies found that SMEs compose the majority of those companies in BEV niches [65, 83]. Indeed, as discussed previously, new entrants such as Tesla and BYD are contributing strongly to the development and dissemination of BEVs.

In the existing ICEV based automotive industry, smaller suppliers and SMEs have marginal roles. Nevertheless, various opportunities are opening up for those companies with a transition from ICEVs to BEVs [84]. While carmakers and Tier 1 suppliers are increasingly developing and implementing BEV innovations, they are also looking outside the organizational boundaries in search for deep specialized knowledge and expertise owing to the specialization and the speed of new technical developments. In this regard, with the transition, SMEs are having more opportunities to capitalize on their innovations [85]. There are five key areas where new opportunities are emerging: a) to reduce the total cost of ownership of BEVs by developing battery technologies and new business models b) to overcome the range problem by developing new solutions c) to ensure energy supply and optimize energy usage by developing software solutions d) for recycling and e) for new niche market BEVs [70].

SMEs are also very significant for the economic growth. In fact, the EU can achieve both economic growth and emission reduction targets by supporting the SME development [84]. Aligned with such perspective, EU aims growth by promoting successful entrepreneurship and improving the business environment for SMEs with policies designed for assisting SMEs at all stages of development. The Small Business Act for Europe articulates this commitment. At the EU level, green transport research, technical development and innovation is supported with “Horizon 2020” program. It also provides “SME Instrument program” providing full-cycle business innovation support specifically for SMEs.

Although the emergence of the BEV sector has provided opportunities for SMEs to become part of a developing supply chain, they require financial support, strategic partnerships (especially for contracting with larger organizations) as well as technology protection support mechanisms for further exploiting the opportunities and accelerate the technology development [84]. On the other hand, diversifying established firms such as Continental, Michelin or Evonik might also require additional support or industry level intervention (higher pressure on ICEV regime by political actors) to be more active in the BEV industry. However, to enable the suitable support, the requirements of these companies need to be clearly identified and specific strategical interventions need to be developed at the EU level.

## 5 Challenges and Strategies

There are several ongoing transition-related activities at multiple levels in the European Automotive System. In order to accelerate the technical change and achieve the 2050 target, some measures might be taken for challenging the factors limiting the new technology, as given below:

- A technical transition in the automotive industry is very unlikely to happen by itself within an acceptable period of time ensuring the EU`s 2050 road transport decarbonisation pathway. To achieve the 2050 target, suitable EU level and county level policies need to be implemented in a timely manner. To support that, robust ex-ante policy intervention evaluation frameworks are required. Such frameworks might have the potential to support national governments in: identifying and improving the dynamics of BEV innovation instruments more effectively, validating results and impacts of instruments on development of BEV technologies and selecting the most appropriate instruments for their country based on their specific transition goals.
- BEVs have a completely different value structure compared to ICEVs. A BEV comes along with approximately 63% higher value added, which is mainly generated at the supplier for the battery cell. Currently, the battery production is dominated by Asian companies and Tesla´s Gigafactory is expected to create a huge impact in the battery industry. Owing to its high value-add as well as strategic importance, more companies are also expected to enter the battery value chain. In this regard, although the European Carmakers have strong competences in vehicle production, engineering and qualified personnel, they need to re-evaluate their make or buy decisions regarding BEV drivetrain, continually innovate through investment, strengthen the links with the R&D sector, and develop and adopt innovative business models. The strategic partnerships might also be suitable to reduce the risks during the transition period.
- SMEs and diversifying established firms are increasingly entering to the BEV value chain with innovative products and services. However, these actors need to be supported to accelerate the technical transition. Besides, SMEs play a very significant role in competitiveness owing to their ability to innovate, increase employment and contribute to economy. Maximising SME engagement and benefit from the transition to BEVs is therefore significant due to their potential in triggering economic development and innovation via the exploitation of emerging BEV business opportunities. Support measures for SMEs especially in three key areas, namely protecting intellectual property, establishing relationships and funding investments might be considered. Additionally, the requirements of diversifying established firms might be revealed and particular measures to satisfy these requirements can be developed and implemented to further assist the technical change.

## 6 Conclusions

2050 GHG reduction target of the EU is an ambitious but also a necessary goal in terms of complying with the Kyoto Protocol of the UNFCCC`s 2°C target. In the automotive industry context, achieving such target requires a technical transition from ICEVs to BEVs, which will not be motivated by single factors. This paper provided a way of achieving fundamental changes in the automotive value chain by analyzing and challenging the factors that limit the new technology. Key outcomes for the study include:

- A transition from ICEVs to BEVs might be possible with an industrial structure which favors the production and consumption of BEVs.

However, to achieve such architectural change, BEV technologies that are developed in niches by incumbent companies and new entrants need to be further developed and prescriptive policy interventions need to be implemented.

- There are several instruments governments might use for promoting BEV technologies. The high diversity of instruments together with the increasingly apparent need for urgency in achieving a transition to a more sustainable mobility, means that ex-post analysis is increasingly inadequate to the task of guiding the effective choice of policy interventions. To evaluate various policy measures and enable the pre-implementation analysis of those measures, robust ex-ante frameworks need to be developed.
- A technological transition in the automotive industry requires considerable changes in the value-add creation for carmakers. Some new entrants have already started investing significantly for occupying the high value-added fields. This can be seen especially in the case of battery value chain, which is the highest value-add part of the BEVs. The battery production is dominated by Asian companies. Therefore, European Carmakers need to re-evaluate their make or buy decisions and capture the high value-add activities. To support that, new business models need to be developed and implemented.
- SMEs are very significant for achieving the GHG reduction target as well as for the competitiveness of the European Economy. However, they need more support for protecting technology, establishing relationships and funding investments. Such kinds of measures might further motivate SMEs to become a part of the emerging BEV-based value chain. The requirements for the diversifying establish firms also need to be investigated and specific support measures for these companies need to be implemented.

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**Author´s Address**

***Fatih M. Özel[1] PhD. (Corresponding Author)***
OECON Products and Services
Hermann-Blenk-Straße 22,
38108 Brunswick, Germany
oezel@oecon-line.de