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The Development of the E-Mobility Supply Chain in Europe - Results of the European Project ENEVATE

Christian-Simon Ernst[1,2,*], Fatih Özel[3], Huw Davies[3], Ingo Olschewski[1,4], Michael Pieper[1,5]
[1]*AutoCluster.NRW, Kölner Str. 80-82, 45481 Mühlheim/Ruhr, Germany*
[2]*Institut für Kraftfahrzeuge – RWTH Aachen University, Steinbachstr. 7, 52074 Aachen, Germany*
[3]*Institute of Mechanical and Manufacturing Engineering – Cardiff University, Newport Road, Cardiff CF24 3AA, UK*
[4]*Forschungsgesellschaft Kraftfahrwesen mbH Aachen, Steinbachstr. 7, 52074 Aachen, Germany*
[5]*Agiplan mbH, Kölner Str. 80-82, 45481 Mühlheim/Ruhr, Germany*
**presenting author: ernst@autocluster.nrw.de*

Abstract

In reaction to the megatrends emission, urbanization, and peak oil, the automotive industry is exploring Electric Mobility. The introduction of E-Mobility is accompanied by significant changes in the supply chain for vehicles. The European Network on Electric Vehicles and Transferring Expertise (ENEVATE) aims to facilitate and support the accelerated introduction of electric mobility in North West Europe (NWE) through structured transnational cooperation between public authorities and business representatives. Therefore, the ENEVATE partners investigate the implications of E-Mobility on the supply chains, the infrastructure, the markets and future mobility.

This study focuses on the implications for the upstream supply chain and aims at the derivation of recommendations for the stakeholders politics, automotive manufacturers and suppliers, especially small and medium sized enterprises. Therefore, a production structure analysis, make or buy analysis, value-add analysis, white spot analysis and an international benchmark of competencies has been performed. It was found that the NWE region has a good potential for the development of a successful BEV industry. Crucial for the success will be a linkage and knowledge transfer between the stakeholders from the electronics industry and the automotive industry.

Keywords: supply chain, industry, policy

1 Introduction

In March 2007, the European Council set clear goals: Reduction of 20 % of the total energy consumption; 20 % contribution of renewable energies to total energy production; and significantly a 20 % reduction of greenhouse gases (GHG) below 1990 emissions. In setting the emission reduction goal it was recognised that the transport sector, and more importantly the automotive sector, had a significant role to play. In 2005, 19 % of total EU GHG emissions and 28 % of CO_2 emissions were linked to transport. Moreover, more than 90 % of all EU transport emissions were due to road transport [1].

The pressure is on the automotive sector to adopt alternative propulsion technologies that have lower or even zero direct CO_2 emissions. In principle, electric propulsion is a technological alternative which could be ready to use in an acceptable period of time. However, a move to electric propulsion or e-mobility poses more than a technological challenge for the automotive sector. The current business structure within the automotive sector is built on cost efficiency and long depreciation cycles. This limits the speed of innovation and creates entrance barriers for newcomers to the automotive sector and the adoption of breakthrough innovations.

To facilitate and accelerate the introduction of e-mobility in the North West Europe region the INTERREG IVB North-West Europe (NWE) Programme has funded the ENEVATE partnership [2]. The partnership aims to boost innovation and competitiveness of the developing electric vehicle sector through structured transnational cooperation between public authorities and business representatives. As part of its remit, the ENEVATE Partnership has undertaken a series of analyses to explore the challenges facing the NWE automotive sector in the transition to e-mobility and to develop a set of strategies to support the development of a commercially strong electric vehicle sector.

2 Background

Globally, the vehicle fleet numbers 850 million [3], consumes 180 billion gallon of fuel annually [4] and accounts for near 61 % of oil use [5]. Unchecked, it is reported that known oil reserves will be depleted in as few as 45 years [5]. Combined with the pressure to reduce greenhouse gas emissions, the pressure is on the automotive industry to develop sustainable transport solutions. Most authors now converge on the idea that electric propulsion or e-mobility represents the most viable short-term solution [5; 6; 7; 8; 9; 10; 11].

Whilst viewed as a solution, the move to e-mobility also comes with its own set of challenges. The drive to decarbonise the transport sector will require the mass application of electric vehicles. Forecasts are predicting that battery electric vehicles or BEVs will hold a market share of 2-5 % in 2020 [12] and that the stock of BEVs will grow to about 1.2 to 1.9 million [13]. To realise this, new BEVs and their components have to be developed and production lines have to be built. The move to mass e-mobility in the near term future will introduce significant changes in both the up and down stream value creation processes.

The major problem faced by the established automotive sector deals with the high adaptation costs. The automotive industry is an extremely capital intensive sector and the main issues in investing in new technology are: capital intensity; cost requirements; and amortisation of sunk costs [14]. The majority of auto manufacturers have limited expertise and intellectual property in the main technology components of electric vehicle technologies, especially in electrochemistry and power electronics [9]. The expertise and economies of scale do not exist within the current automotive sector and the costs for employing them is considerable [15]. A further issue is the lack of standards for quality and performance in this new supply chain and this only serves to increase the risk and further distance the automotive sector from these new technologies.

Governments have looked to incentivise e-mobility, but the projected business returns do not create enough motivation within the automotive sector. The result, OEMs give priority to other types of investments in the current market which have more visible and faster return on investment [14]. The end result is that in 2011, there were fewer than 30 different electric vehicle models produced by OEMs. There is also a low proportion of private ownership. For example, most of the vehicles registered in Germany are owned by companies, mostly for testing purposes, and not by the private public sector [16]. This is far removed from national Government aims and societal objectives [5].

3 Methodology

To support the transition to e-mobility, competencies need to be found and connected to develop a strong supply chain. As part of the ENEVATE project a database was developed in order to capture the competencies within the existing internal combustion engine (ICE) and nascent e-mobility sectors across North-West Europe. The approach used to develop this database is outlined in Figure 1. The final database provides both a list of relevant companies like system and component suppliers, universities and R&D centres.

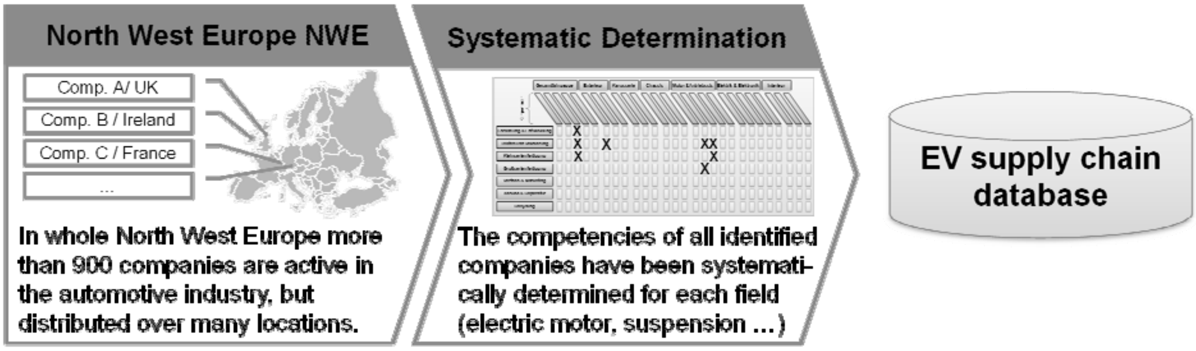

Figure1: EV Supply Chain Database

The analyses of this database were used to guide the development of a number of strategies that aim to facilitate the development of a commercially strong BEV sector in the North-West Europe region. These analyses are described in the following sub-sections. Furthermore, the database is an online tool, integrated in the www.enevate.eu homepage, which helps companies to identify possible strategic development and production partners for BEV.

4 Production Structure Analysis

The foundation of the automotive sector in North-West Europe is the supply chain. A supply chain can be thought of as a single virtual organisation involving several business units such as manufacturers, suppliers, distributors and retailers, and operations [17]. Its purpose is to obtain raw materials, transfer those raw materials into consumable products, and distribute those consumable products to retailers and customers [18]. The productivity of a supply chain is critical as companies compete via their supply chains rather than competing alone [19; 20; 21].
Today, the supply chains in the automotive industry are closely linked. System integrators integrate the modules and components produced by either technology specialists or process specialists (Figure 2). The growth of system integrators has resulted in a decrease in the total number of directly linked suppliers for the vehicle manufacturer.

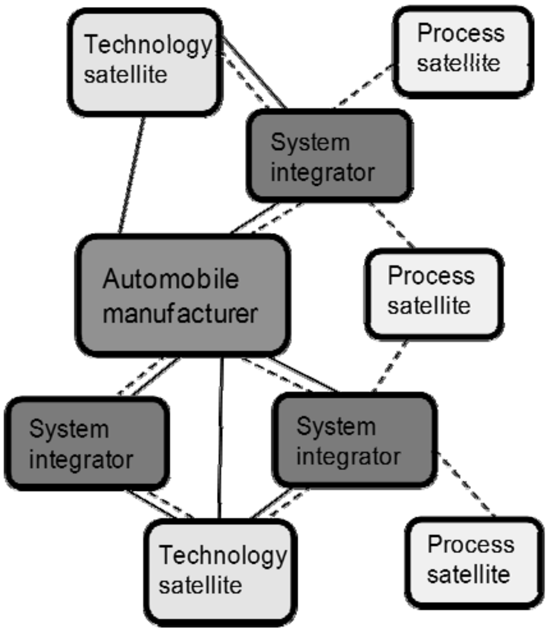

Figure 2: Production structure of the ICE of today [Dodel 2004]. The dashed lines represent joint logistics / supply chain. The solid lines represent joint product development

If BEVs are to be competitive in the market place, the success will depend on the efficiency of the supply chain [19].
The present BEV fleet is a mix of 1st and 2nd generation designs. The 1st generation battery electric vehicles are largely based primary on classic ICE vehicles (conversion design). Examples include E-WOLF [23] and German E-Cars [24]. Analysis of the ENEVATE database accompanied by site visits to a number of BEV manufacturing facilities across NWE showed that the production process for BEV is characterized by small job lots driven by irregular demand and a “one:many” relationship with suppliers (Figure 3).

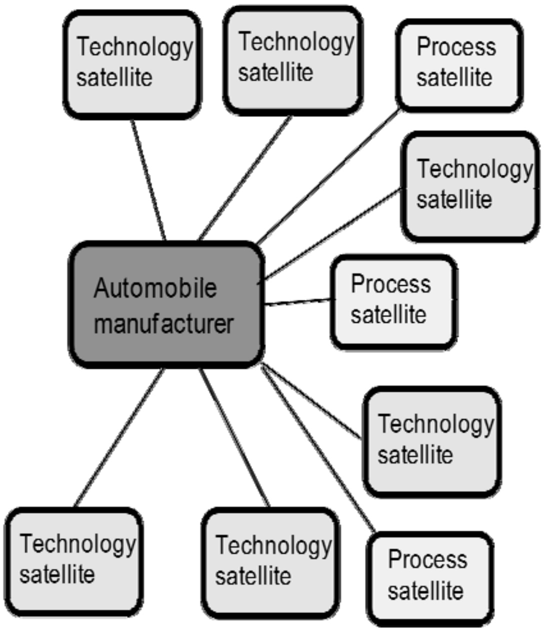

Figure 3: Production structure of the typical BEV today

The 2nd generation of BEV move towards a purpose design, which may include flexible body design concepts that are open for any drive train like gasoline, LPG or EV. The purpose design will realize more revolutionary design changes i.e. also in the chassis. Examples of this move to a purpose design include the Nissan Leaf [25]. This 2nd generation design also represents a move towards the mass-production if not necessarily reflective of the production structure of the ICE of today due. However, the increase in production heralded by the introduction of 2nd generation vehicle designs will encourage the establishment of system integrators.

In summary, with the move from 1st and 2nd to 3rd generation designs it is expected that the production network will be required to evolve from the pre-series models with a "one:many" relationship to an "one:few". It is expected that this transition will be facilitated by increase in demand and higher production numbers that will enable the production process to be synchronized and enable the establishment of system integrators, who offer the full electric drivetrain as integrated solutions.

5 Make or Buy Analysis

A make or buy analysis provides an insight on the future task sharing. Companies consist of resources, assets and capabilities which are defined as a portfolio. The vehicle manufacturer (OEM) focuses on their competencies and positioning these competencies in their portfolio i.e. the decision to make or to buy. To position the competencies in portfolio, two dimensions are considered: significance of the resources for generating value for the customers and superiority or inferiority of the resources in terms of their competence strength [26].

To explore changes to the supply chain, the ENEVATE partnership conducted an analysis based upon competency mapping. The analysis was primarily focused on the drivetrain area as this is expected to be the main differentiation between the ICE and the BEV. For the ICE vehicle it was found that the motor and the gearbox were the highest value added components in the drivetrain area (Figure 4 - numbers 1 and 3). The competence strength was the highest for the motor. This was not unsurprising as all major OEM view the motor as a core competence. In contrast, both the exhaust system and the motor auxiliaries were viewed as low value added components and the drive electronics as medium added value. Consequently, whereas internal production by the OEM was seen as a suitable strategy for motor and gearbox, supply strategy was seen as suitable for exhaust system, motor auxiliaries and drive electronics (Figure 4 - numbers 2, 4 and 5).

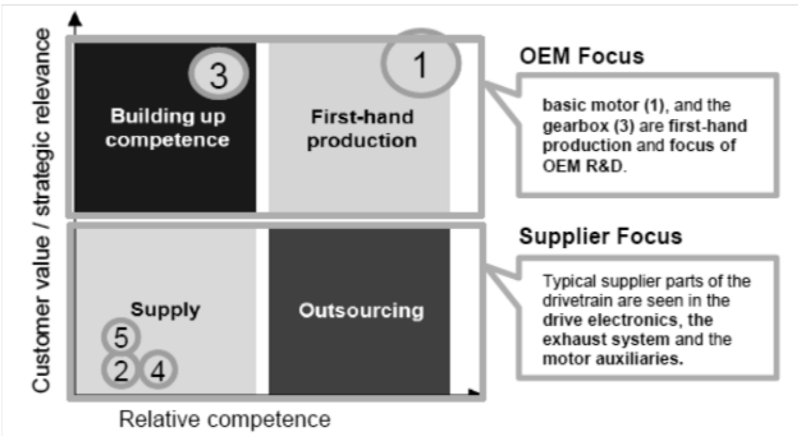

Figure 4: For the ICE vehicle the basic motor (1) and the gearbox (3) are first-hand production and focus of OEM R&D.

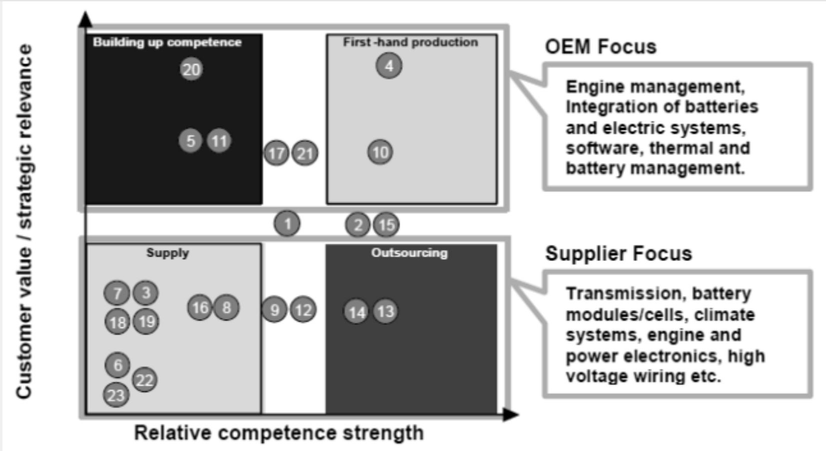

Figure 5: OEM and Supplier Focus for the BEV

A similar analysis for the BEV resulted in a different outcome. Engine management, integration of batteries and electric systems, software, thermal and battery management were all viewed as high value add and therefore suitable for internal production. This meant the following systems required for production of BEV would need to be bought in from suppliers: transmission, battery modules/cells, climate systems, engine and power electronics, high voltage wiring etc. This represents a considerable challenge for the OEM as the expertise for the value-add activities are under-represented within these organisations. To buy-in this expertise would dilute the value-add and reduce the profit that can be leveraged out of the manufacturing activity. The results of this analysis are shown in Figure 5.

6 Value Add Analysis

The change to the make or buy analysis has implications of the success, or otherwise, of the OEM and supplier communities in North-West Europe. The move to electric propulsion will alter the players in the supply chain and create new players such as battery cell producers and suppliers of electric motor components. Conversely, the OEM will need to ensure that they continue to add sufficient value to the product to remain competitive in the market. An assessment was therefore undertaken by the ENEVATE partnership in order to determine the value added difference between ICE and BEV.

For the assessment of the ICE vehicle, approximately 33 % of the total value added per vehicle is being generated in the drivetrain (Figure 6). Of this added value nearly two thirds is attributable to the basic motor and gearbox – both the mainstay of the OEM. The remainder – drivetrain electronic, motor ancillaries and exhaust system – are primarily the preserve of the supplier.

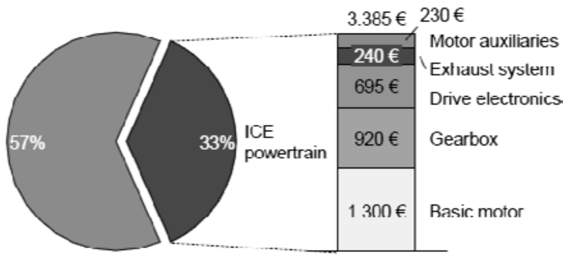

Figure 6: Value added for the ICE [27]

For the assessment of the BEV, the value added by the drivetrain is a far more significant 60 % of the total (Figure 7). Of this nearly 85 % is attributable to the battery, which is currently the preserve of the supplier. The electric motor and power electronic contribute approximately 6 % of the total power train value, whilst other parts of the BEV power train only add 3 % more value. These components are almost all the exclusive preserve of the electronics industry at the moment.

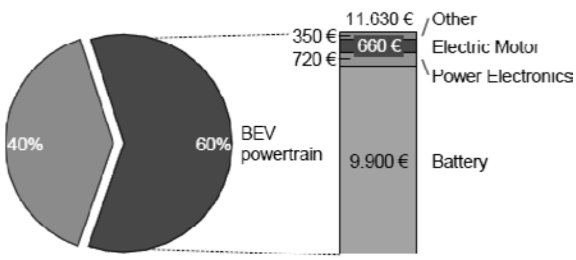

Figure 7: Value added for the BEV [28]

In moving from ICE to BEV there is going to be a considerable change in the value-add creation for the OEM. Firstly there would be a loss of value-add associated with the ICE internal combustion engine and gearbox as well as additional components which correlate with a design optimized on

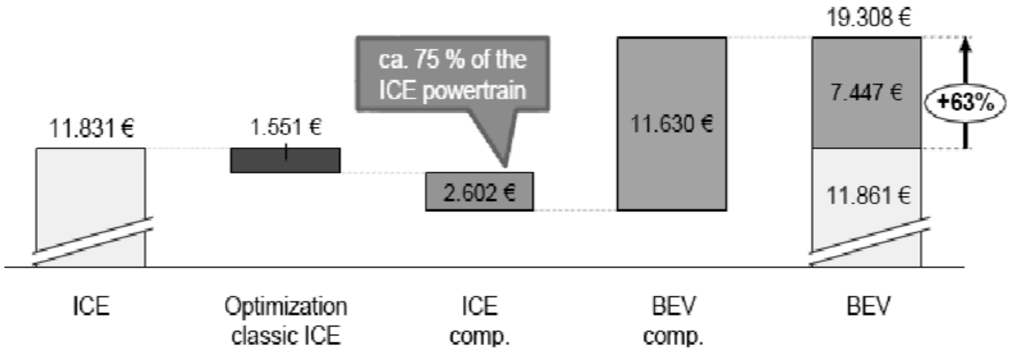

Figure 8: Change in the value added creation between the internal combustion engine (ICE) and battery electric vehicle (BEV)

an ICE, i.e. components for thermal engine management or NVH (columns 2 and 3 of Figure 8). Secondly, there would be additional value-add tied to the BEV component costs, which at this time are the exclusive preserve of the supplier (column four of Figure 8).

Overall, the total value-add would be far higher for the BEV – by approximately 63 %. However, the move from ICE to BEV could represent a significant loss in value-add from the point of view of the OEM – circa 75 % of the present value added by the powertrain. The OEM will have to claim their part in the electric component part of the supply chain if the value added associated with the ICE vehicle is to be maintained.

7 White Spot Analysis

The ability to add value to the BEV supply chain is dependent on the competencies and capacity of the automotive sector. In North-West Europe (NWE) more than 900 companies have been identified through the ENEVATE study as being active in the automotive sector, but geographically they are distributed over many locations. The ENEVATE partnership systematically determined the competencies of all identified companies in regards to battery electric vehicles (electric motor, suspension, etc…). With this tool a SWOT analysis was performed to identify white spots in the supply chain for battery electric vehicles for each region.

According to the analysis, the electric vehicle technologies are mostly at Research and Development status which means they are not yet commercialised. From the manufacturing perspective, almost all significant battery electric vehicle components exist in NWE region. The analysis also showed that testing and validation of battery electric vehicles are also presently ready within the region. Although reuse and recycling is covered it is likely to pose a problem for battery electric vehicles if numbers are to increase significantly. This requires further investigation.

The electric vehicle database and, hence, white spot analysis does not include all companies that have a potential contribution to electric vehicle technology in Europe as this is a continually evolving arena. To develop a stronger database and more precise results, information from other companies is aimed to be gathered and integrated with the existing system.

8 Competitor Analysis

International benchmarking was also required to establish the position of North-West Europe in the battery electric vehicle sector in comparison with competing regions. An interview study was conducted with stakeholders (OEMs, 1st tier suppliers and non-governmental organisations) from the automotive industry in Europe and the USA. The interview questions were developed in order to both inform the interviewees about e-mobility development in North-West Europe and learn their opinions about the current and future development in the their region. The key results of this study are presented in Table 1.

As can be observed, the USA is very advantageous for accelerating the e-mobility and leading the EV industry owing to high R&D investments, government support and incentives, better infrastructure and legal situation, more practical organizations, more accessible tools in universities, lower labour, production and energy costs, and strong cooperation among cities. It is however expected that R&D investments will decrease to low or medium level in the future; this brings significant risks to the expected leading role of U.S. in e-mobility and presents opportunity for North-West Europe.

Table 1: US interview answers for the competitor analysis

Main Topics		Interviewee Answers
R&D	Current R&D	R&D is high in U.S., medium in Europe and low in Asia
	Future R&D	While it is expected to decrease to low or medium level in U.S., it is expected to increase in Europe and Asia with Private Sector`s investments
Product and Market Potential	Preferred Vehicle in 2020	Preferred vehicle segment will be C-D with a share of 5-10 % in U.S., B-C with(4-8 %) in Europe and A-B and scooter (10-15 %) in Asia
	EV market share in 2020	PHEVs will dominate the market with 76% market share (BEVs 24 %)
	Interoperability	Cooperation exist between cities and companies for building charging stations
Component Analysis	Make or Buy Strategy	Battery System: Supply Strategy , Electric Motor and Power Electronics: No clear strategy
	Customer Value	More practical thinking in the U.S. and more environmental thinking in Europe. Reliability, appearance and emotion are key attributes for customers in U.S.
	Standardization	Potential exists on battery cells, motors and power electronics
R&D and Production Locations	R&D Locations	U.S. is more advantageous than Europe owing to higher incentives and tax credits, more accessible tools in universities and more practical organizations like Fraunhofer
	Production Locations	U.S. is more advantageous than Europe owing to higher tax credits, better infrastructure and legal situation, and lower labour, production and energy costs.
Utilization	Energy Generation	Very strong and close cooperation between the automobile industry and energy suppliers (Resulting in several joint projects)
		No mandatory renewable energy targets on federal level, but there is in some states
		Government buys EVs for own fleet (such as postal services and military)
	Recharging	Low voltage is expected to be primary source for battery charging
		Charging stations are not widely available only in some cities such as Chicago
	Customers	Full-Service-Offers are existing or expected to be soon
		Cooperation exists among cities, OEMs and energy suppliers
		Realized Incentives are tax refunds, special lanes, free charging, free parking, subsidies of 7000-8000 $ and emission free zones
	Ownership Models	The primary ownership model for EVs is expected to be same as for ICEVs
		Better Place business model and lease mobility are not supported
Global E-Mobility Development	Chances	Energy security and Independence from fossil fuels
		Smart grids
		Combination with renewable energies
		Governmental fleets as pilots for customers
		New driving experience
		Green house gas effect discussion
	Risks	Safety of batteries
		Performance of batteries
		Market acceptance
		Infrastructure
		Carbon footprint with energy generation (i.e with coal)

9 Strategic implications

Electrified drivetrains, PHEV and BEV, will be a part of all automotive manufacturers' vehicle portfolios in future. Conventional combustion engines, gasoline and diesel, will play a dominant role within the next years, even after the year 2020. But all actors of the automotive industry have realized the long term importance of electrified drivetrains and set a new focus for the research activities.

The presented analysis of the automotive sector in North-West Europe bases on the assessment of the old and new production structures, the change in the value add distribution, the competency mapping and the international benchmarking. The core challenge in building a new industry sector is seen in the establishment of a new and strong value chain between actors that haven't had collaboration before. Hence, policy makers, vehicle manufacturers and automotive suppliers have to set the correct course of action.

Policy Makers

The core interest of policy makers is seen in the realization of long term visions like the "low carbon industry". Therefore, they have to define the framework conditions for the e-mobility develop-

ment. The ENEVATE project supplies an important component with the competence mapping to set successful framework conditions. It shows the status quo of the competence distribution for electrified drivetrains in the NWE region.
It becomes obvious, that politics need to take action to improve the networking between all stakeholders, especially from the different industry sectors. A real challenge is the know-how transfer from research and development results, generated by universities or research companies, to market ready products, produced by a manufacturer. The initiation of joint research projects can support both, the know-how transfer from research experts to industry and the generation of new research results to close the gap for key technologies like the battery cell chemistry and technology.
Moreover, it is generally important to improve the attractiveness of the European business location to attract new companies to invest in the region and to stimulate the existing industry to broaden their activities. The international benchmark indicates improvement potential as seen e.g. in the reduction of bureaucracy.

Vehicle Manufacturers

The electrification of the drivetrains leads to numerous challenges for today’s automotive industry. Nowadays, the manufacturing of BEVs is characterized by small job lots, irregular demands and relationships to many small suppliers. High adaption costs and a lack of standards for quality and performance in the value chain are significant challenges, which OEMs are presently faced with. However, the competitiveness of a BEV is directly connected to the efficiency of the value chain. Pushed by an increasing demand and higher production numbers, the production process will be progressively synchronized and develop from batch production to mass production. This will lead to higher cooperation with system integrators, which offer solutions for the electrified drivetrain. In return, this results in a decrease of the total number of suppliers participating in the supply chain. Furthermore, new production plants with high capacities particularly for battery systems have to be implemented.
The value-add of BEV compared to ICE will significantly change. This influences the manufacturer’s make-or-buy strategy. High value added components like engine management, integration of electric systems, software, thermal and battery management are intended for internal production. In contrast transmissions, battery cells, climate systems, engine and power electronics are meant to be bought from suppliers. Although there will be a significant increase of value-add of the complete vehicle by approximately 63 % the OEM will lose nearly 75 % of value-add by the powertrain. This will lead to a reduction of the manufacturer’s profit. Hence, these challenges can be handled by implementing strategic alliances or acquiring the required competences from competitors.
Furthermore it is necessary to develop an early strategic orientation to achieve a well-established market position. The transition to an increasing electrification of the drivetrain will require high investment. This implicates a high economic risk for the industry, especially if reasonable sales numbers are not generated.

Automotive Suppliers

The chances for electronic experts as automotive suppliers are often discussed in the literature. In fact, the electronic branch does have a significant innovation and knowledge advantage concerning the key components of the electrified drivetrain. Especially the fields of electric motors, power electronics and battery cells are developed by experts from the electronic industry. Nevertheless, the automotive integration is a challenging task that requires full vehicle knowledge, which is present only by today’s OEM. Nowadays, the automotive industry tries to reduce that knowledge gap by close research alliances with small and medium sized enterprises. But these relationships won’t last in a long term perspective. Only companies which can supply technology solutions in volume with automotive standards for competitive prices will survive. The current system suppliers of the automotive industry will play a major role in future concerning this capital intensive task. Therefore, SMEs should check their strategic alignment towards a sustainable cooperation with an OEM or system supplier.

In conclusion the ENEVATE project shows that the NWE region is well prepared for the introduction of electric mobility. The introduction will be a slowly evolving process which doesn’t turn around the whole industry revolutionary. In accordance with hybrid and plug-in hybrid cars, the components of the electrified drive will achieve resonable volumes. In a long term perspective, system suppliers will offer solutions for the complete electrified drive train and integrate innovation from SMEs in their solutions.

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Authors

Christian-Simon Ernst is currently working as research associate at the Institut für Kraftfahrzeuge at RWTH Aachen University in the strategy and consulting department after studying mechanical engineering and business economics at RWTH Aachen and POSTECH University. The focus of his research was the market and supply chain development for battery electric vehicles within the ENEVATE project.

Fatih Mehmet Özel is a PhD student at Cardiff University. He previously studied Manufacturing Systems Engineering and Industrial Engineering for MSc. and BSc. degrees respectively. Currently, he is looking at the role of EV technology and business. The focus of his research is understanding the role of technology and sunk investment in the adoption of EVs by the automotive value chain and determining the risk factors to understand how quickly and deeply EVs will penetrate the market and whether or not it will become a sustainable market segment.

Dr Huw Davies is lecturer in Mechanical Engineering. He was previously a member of the Vehicle Engineering Group at the Transport Research Laboratory. At Cardiff he has developed the transport research theme. Safety, mobility and emissions are at its core. The universal goals are zero collisions, zero congestion and zero emissions. Dr Davies currently leads Cardiff University's multidisciplinary Electric Vehicle Centre of Excellence. The Centre undertakes research on all aspects of Electric Vehicles including; design and manufacture, innovative business models, consumer expectations and incentivisation, energy supply and charging infrastructure.

Ingo Olschewski studied business economics at RWTH Aachen and is currently senior manager at the Forschungsgesellschaft Kraftfahrwesen mbH Aachen (fka) in the strategy and consulting department. The focus of his research was the market and supply chain development for battery electric vehicles within the ENEVATE project.

Michael Pieper is an engineer and project manager with a brought experience in automotive projects. He has been engaged in either, industrial and public activities, focussing on electric mobility during the last years.
Currently Michael Pieper is part of the cluster management team of EffizienzCluster LogistikRuhr, one of the largest R&D clusters in logistics worldwide. For ENEVATE he represents the AutomobilCluster.NRW and is member of the steering group.