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Light Electric Vehicles in Baden-Württemberg – Potential for industry and new mobility solutions?

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Summary

In the State of Baden-Württemberg, there is a world-leading cluster of automotive production with major manufacturers in the premium segment and major automotive suppliers. By contrast, LEVs are barely in use or as a development or production location. In the study the potential of Light Electric Vehicles (LEV) for the industry in Baden-Württemberg and for the transport sector was analysed. In the following paper an exemplary presentation of results can be found.

Keywords: light vehicles, mobility concepts, industrialization

1 Initial Situation

The State of Baden-Württemberg, situated in the South-West of Germany, is traditionally known for its automotive industry and formally for the production of premium cars and engineering. Over the past 130 years, the region has gone from the cradle of the automobile industry to a major automotive ecosystem. Internationally well-known OEMs like Daimler or Porsche and suppliers like Bosch, ZF or Mahle are located in the region. In addition to that, many small and medium sized enterprises and hidden champions are situated in Baden-Württemberg, too. Around 310,000 people are directly employed in automotive construction. Besides that, there are many jobs in related industries, which directly depend on the automotive industry or the supply chain. In total, the cluster automotive industry in Baden-Württemberg provides jobs for around 470,000 people. [1] As a result 6 % of the working population in the region is employed in the automotive sector. That's why the automotive industry is the most important employer in the region.

Many people are commuting to work every day. In the Region of Stuttgart (state capital and surroundings) for example, around 400,000 persons need to cover a certain distance between work place and home. The consequences are high volume of persons using the public transport and in addition to that severe traffic jams on the streets in the metropolitan area. Apart from the bigger cities, Baden-Württemberg consists of many rural areas characterized by less public traffic connections. Especially in these areas efficient first mile solutions are needed, which present an acceptable alternative for the own car.

Many municipalities in Baden-Württemberg face the challenges with fine particles and NOx pollution. The European Commission sued Germany for abuse of regulatory limits with regards to nitrogen dioxide (NO_2). The need for a sustainable and emission free mobility is rising sharply.

Light electric vehicles seem to be an interesting opportunity to solve some of the transport challenges. The field of light electric vehicles (LEV) is sparsely developed in Europe and in Baden-Württemberg, both in the industry and in the use on the streets. But LEVs might be a solution approach to diverse challenges in the region. In other countries worldwide, especially in Asia, LEVs are already quite popular and have spread widely. LEV offer new mobility concepts, especially for urban areas, with less parking space and more space for people. The LEV, which are small and quiet, can contribute to an improvement of quality of life.

Another important point for taking LEVs into account is the technological transformation of the automotive industry leading to electrified, highly energy-efficient and smart mobility solutions as well as the potential for digitization. All these changes will not only dramatically change the car itself. Many other areas, such as commerce and the energy industry, will be affected, too. From this point of view, it is also important to consider new business cases for nowadays automotive industry.

Therefore, the state agency for new mobility solutions and automotive Baden-Württemberg, e-mobil BW published a call for tenders in mid of 2018 for a study on the economical relevance of light electric vehicles for companies in Baden-Württemberg. The second main issue of the study is, to which extend new formats of vehicles like LEVs can make a contribution to a more sustainable and ecofriendly mobility in Baden-Württemberg.

A consortium consisting of German Aerospace Center (DLR) and the IMU Institut GmbH were awarded the contract of the study. In the following, we are going to present the scientific approach and the main results of the study. The study is not published yet and will only be published in German. [2]

2 Scientific approach

Due to the fact, that the number of LEVs on the roads is narrow by now, the market and data situation is non-transparent or simply not available. In addition to that, an incoherent international regulation is complicating the collection of statistical data. The difficulty in data corresponds to vehicles numbers as well as to employee statistics.

As a result, the consortium worked with interviews of experts in order to get an overview on the current market situation. For the analyses of the potential of use, the consortium analysed the data collection "Mobility in Germany (MiD)", which is a nationwide survey of households on their everyday traffic behaviour in Germany. [3] This study was conducted during 2016 and 2017 with 135,000 households and the results were just available in the beginning of 2019. The study is a common project of the German Federal Ministry of Transport and Digital Infrastructure (BMVI) as well as regional partners. The MiD "provides up-to-date data on important factors influencing mobility and forms the basis for transport models" (see ibid.). For more information on the methodology of MiD, please, refer to the given sources.

3 Definition of the subject of study

Micromobility as term covers several different classifications from "Personal Electric Mobility Devices", "Motorised Mobility Aid Vehicles", "Electric Bike Vehicles" and "Light Electric Vehicles". [4] All different kind of micromobility vehicles are presented in the study, but it would have led too far to analyse the potential for all of the different LEV. Therefore, it was important to define in a first step the object of reflection. We decided for a closer examination of the vehicles, which might have a higher value-added potential in correspondence to the competences of the automotive industry in Baden-Württemberg and to the actual German user behaviour.

In the study the focus is set on cargo bikes with two and three wheels as well as LEVs with three and four wheels. In the European classification these categories are related to L1e-A, L1e-B, L2e, L5e, L6e and L7e.

It is interesting to see, that many prototypes were presented on the automotive shows in the years from 2010 to 2012 and nowadays, but only a few vehicles go into production. Often LEVs are shown to clarify the possibilities for future mobility concepts.

Another important fact is, that only a few LEVs are produced by Original Equipment Manufacturer (OEM). There are also small and medium sized enterprises, which are well-known in the market segment like Kyburz from Switzerland, which is also developing and producing LEVs for the Swiss Post. In addition to that start-ups and supplier are active in the field of producing LEVs. Since 2017 more OEMs such as Seat, Honda or Toyota are presenting studies of LEVs again. This corresponds with the environment requirements and as a result e. g. the ban on vehicles in inner city areas.

Figure1: Focus of LEVs in the study

4 Technical aspects

The analyses make clear, that the European L-category covers a wide range of different vehicles. But all LEVs have in common the fundamental similar basic structure of the powertrain consisting of battery, electric machine, gearbox and power electronics. The powertrain of a LEV thus basically consists of the same components as a battery-electric car, but differs from this significantly in the design and performance of the individual components.

The battery is the highest cost factor for LEVs. In comparison to a battery electric car the relative system overhead costs (€/kWh) are 10-15 % higher for LEVs. The reasons for the costs are the low number of units and the low installed capacity per vehicle. Depending on technology and production quantities costs can be even higher.

For the drive of LEVs both a single, central electric motor and the use of several wheel hub motors is conceivable. Currently produced vehicles are equipped with a single motor, often three-phase asynchronous motors are used. According to experts in production vehicles, the choice of drive with a single motor is based on the fact that the use of multiple motors is more expensive or leads to a higher complexity of the drive system. Concept studies partly use wheel hub motors. From a technical point of view, the required wheel hub motors are available and soon they will also be installed in electric scooters in Asia.

If LEVs, like the examples shown above, are powered by three-phase asynchronous machines, an inverter, like the battery-electric passenger car, provides the required rotating field. For this purpose, it converts the direct current from the battery into alternating current. In addition, the inverter allows the recovery of braking energy by recuperation. In models such as the Twike 3, Twizy, Tazzari Zero and vehicles from Kyburz this is technically implemented and the Microlino will as well enable recuperation.

A DC/DC converter is only required, if an LEV does not have a separate low-voltage battery for a 12 V electrical system. In this case, a high-voltage converter transforms the high voltage of the traction battery into a correspondingly lower voltage.

The charging infrastructure is usually installed on-board at LEVs. They can thus be connected to a power source for charging without an additional charger. The built-in electronics converts the AC voltage of the charging station or household socket into DC voltage for the battery.

The connection to the power source takes place at LEVs usually via a Schuko plug, as it is also used at home. Charging power of up to 3.7 kW (230 V, 16 A) can be achieved on such a household socket with appropriate protection. Although some vehicles offer a Type 2 connector as an option (e.g. the Twizy), charging continues to be single-phase. This also applies when using Schuko adapters on type 2 plugs, which are available on the market. Only adapters approved by the manufacturer may be used.

A three-phase charging, which would allow significantly higher performance, leads to a sudden increase in costs. As a result, single-phase systems are typically used on small vehicles. However, future vehicles like the TWIKE 5 announce charging power of e.g. 22 kW. Another reason for a single-phase charge is the lower energy requirement of LEVs. For a comparable travel distance as for passenger cars LEVs therefore significantly lower battery capacities are necessary. In keeping with the low energy requirement, even low charging power makes it possible to charge the battery in a relatively short time. For example, a full charge of the Twizy's battery takes only 3.5 hours.

Another important factor with regard to LEVs is the security aspect. The topic concerns the vehicle development as well as the type approval and represents a central purchase or usage criterion. However, the importance of this criterion varies among different buyer groups. While safety is often cited as an obstacle to buying three-wheel and four-wheel LEVs, motorcycles are successful on the market. In this case, no crash tests are pre-written for them and the maximum speeds are not limited. Here it becomes clear that features such as driving pleasure can also be a criterion in the choice of transport, depending on the users' interest.

When assessing the safety of LEVs, it is relevant to which kind of vehicle they are compared (e.g. cars or scooters) and the environment in which they are to be used. For example, some vehicles in Tempo 30 zones are a fairly safe means of transport, but at high speeds, e.g. on federal roads classified as unsafe. Compared with cars LEVs are as weaker road users already due to the physical mass or inertial laws at a disadvantage. In Europe, unlike as in South-Korea, crash tests are not required by law for L-category or lower vehicles.

5 Global Market Potential and Market Development

A look at LEVs in an international context shows a fragmented map of different national regulations and vehicle definitions. Many countries have little or no regulations and few statistics on existing vehicles. In addition, the definitions of the vehicles are very different, for example, in terms of weight, power, speed or geometric dimensions. This makes a worldwide comparison hardly possible.

5.1 Asia

The Asian market is very diverse in itself, but the largest compared to other world market regions. In the case of the four-wheel LEVs, the countries Japan and China in particular contribute to this.

In Japan since 1949 regulations exist for so-called kei-cars. Kei-cars have received tax incentives through the national government until 2016. A total of 1.84 million kei-car vehicles were registered until 2017, although no distinction is made between the types of drive, meaning that vehicles with combustion engines are also included. Since the promotion ceased, sales have declined while larger-sized vehicles have been increasingly purchased over the same period [5].

China is LEV's largest market in the world for over ten years. Although no regulations have yet been introduced for these vehicles, the market explodes. Since the vehicles are not registered, the LEV inventory figures are only estimated so far and in 2016 were at about 1.2-1.5 million with an approximate annual growth rate of 50 % since 2014. In 2017, the LEV inventory was estimated at 4 million vehicles [6].

Three-wheeled vehicles are also known as tuk-tuks in many Asian countries and promoted by national strategies (for example, in India or Thailand) to replace the existing fleet of internal combustion engines. In 2018, India's vehicle fleet grew to 1.5 million battery-powered tuk-tuks [7].

5.2 Europe

In Europe, although the definitions are uniformly regulated by the European Directive, the database is still problematic for comparative analysis. Associations, such as The European Association of Motorcycle Manufacturers (ACEM), for example, provide data on four-wheeled electrical LEVs, but only the sales of the members of the association are included in the figures. In addition, there are figures from an EU project sorted by member countries [8]. These figures largely coincide with the sales figures of ACEM.

A significant increase in sales for Europe can be seen in 2012 (see Figure 2). This year, the Renault Twizy came on the market and recorded in the same year a very high sales of almost 9,000 vehicles (Figure 4 2). The chart shows that the Twizy has a significant market share over the years.

The main sales markets for both the Twizy and the other quadricycles are Italy, France, Germany and Spain.

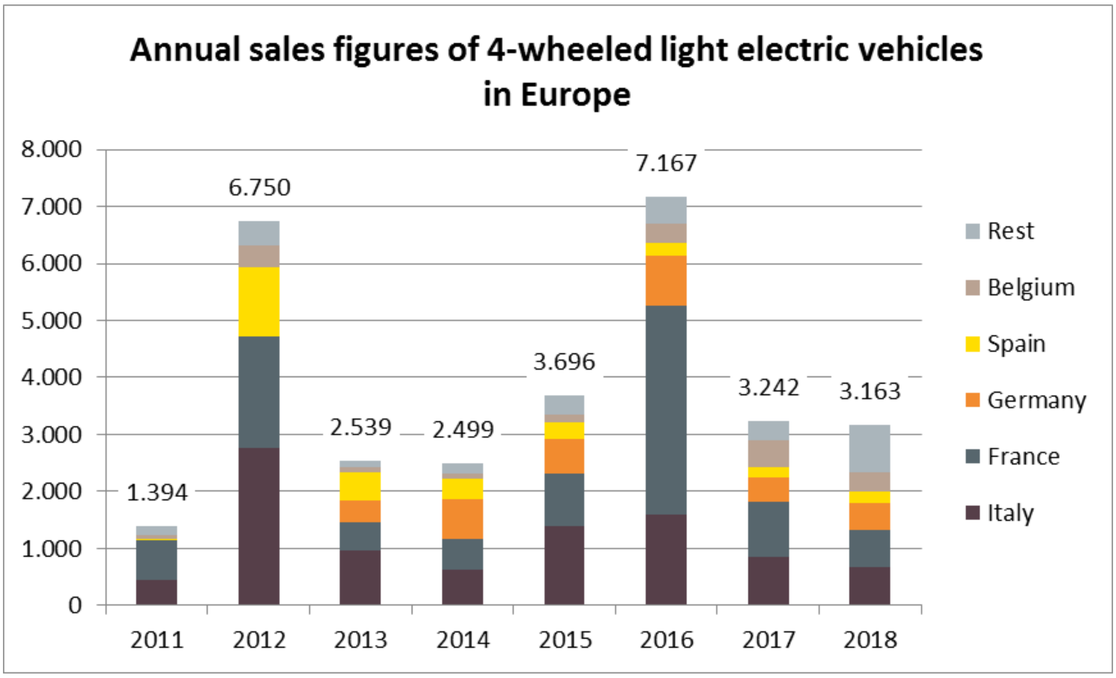

Figure 2: Annual sales of 4-wheeled LEV in Europe (source: ACEM, 2019)

6 Potential of use

In order to estimate the traffic potential and user potential of LEVs in Germany, both for passenger and commercial transport, the following questions are examined on the basis of the data set of the MiD[1] 2017:

- Which part of the traffic volume of passenger and commercial transport could be covered with LEVs at most?

[1] Mobility in Germany (MiD) is a nationwide survey of households on their everyday traffic behaviour. For further information: https://www.infas.eu/projects/infas-project/mobility-in-germany-mid/ [3]

- Which ways could LEVs be used for?
- How big is the circle of potential users of LEVs?
- Which group of people are the potential users of LEVs?

Based on the vehicle characteristics of the considered LEV models, characteristics of tours for which LEVs can be used were determined. If a tour fulfils all these characteristics, it is assumed that a LEV could be used for this tour as well. By doing so, the maximum potential of LEVs can be determined. However, it can be taken into account that this potential would not be fully exploited by switching to LEVs, as other aspects such as the personal preferences of the survey participants or their willingness to buy a LEV also influence the choice of mode of transport. For example, many road users could cycle to work on short commutes but do not do so due to personal preferences. These aspects were not discussed in the MiD 2017.

6.1 Trips with private purpose

Due to the limited scope in this paper, we have to focus only on special results of the study. For commercial potential of LEVs and further examinations, please, refer to the whole study.

To analyse the traffic potentials of LEVs, it is examined which share of the traffic volume (that is the number of routes) and the traffic performance (that is the distance travelled, measured in kilometres) could be replaced. Since the substitution potentials of different LEV models have similar vehicle characteristics, only results for the LEV models EVT Trike, Riese & Müller Packster 80 HS, Aixam eCity Pack (similar properties to Renault Twizy [45 km/h] and Cleanmotion Zbee) and Micromobility Systems Microlino (similar features as Renault Twizy [80 km/h]) are in the focus of the analyses.

Depending on the model, the maximum substitution potential, as it is illustrated in Figure 3, for LEVs is between 17 % and 49 % for traffic volume by trips and between 6 % and 30 % for traffic volume by distance. In particular, the electrical range and the maximum speed restrict the substitution potential here. LEVs with higher ranges and speeds are an alternative, especially on work paths and for shopping: the Microlino could be used on 57 % of all work paths and on 59 % of all shopping trips (see Figure 4).

The maximum substitution potential is only theoretically reachable but not realistic due to many limiting factors as comfort aspects or user behaviour.

The maximum usage potential in Baden-Württemberg varies between 19 % and 43 %, depending on the LEV model and the city. Compared to the maximum user potential in Germany as a whole (depending on the LEV model between 17 % and 38 %), it is slightly higher in the considered Baden-Württemberg cities.

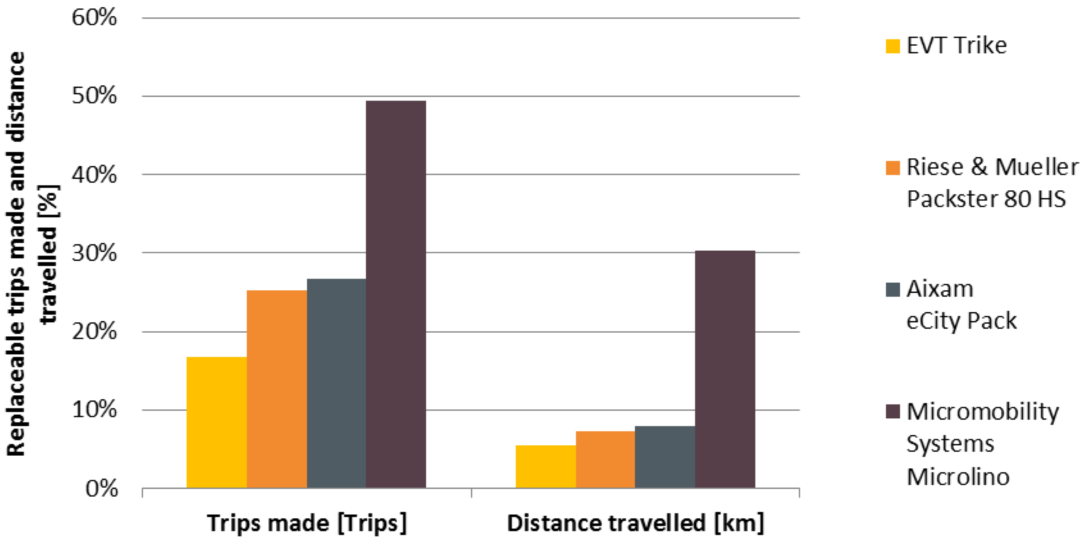

Figure 3: Maximum of replaceable trips and distance travelled in Germany

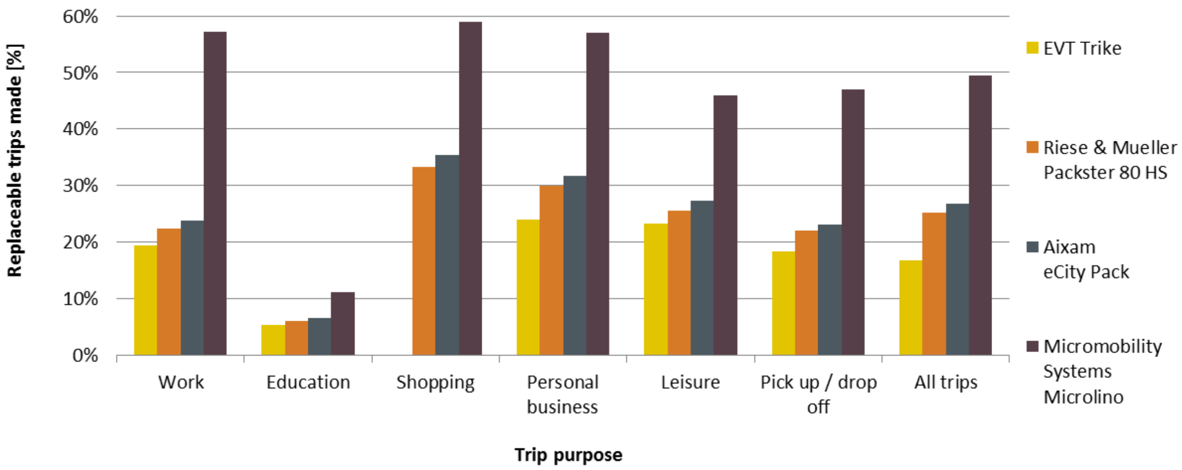

Figure 4: Replaceable trips with regard to trip purpose

In relation to the spatial structure of the place of residence, the larger the city, the higher the potential that a LEV could be used on the day of the survey (Figure 5). While in metropolitan areas, for example, 21 % of the survey participants could use the EVT Trike, in small-town, rural areas it is only 13 %. This is because the inhabitants of small-town, rural areas often have to travel longer distances to carry out their activities (e.g. shopping, visiting the doctor). LEV models with higher electrical range and maximum speed, such as the Micromobility Systems Microlino, would also find slightly more users among metropolitan residents (39 %). The difference, however, is not so great compared to inhabitants of small-town, rural areas (36 %).

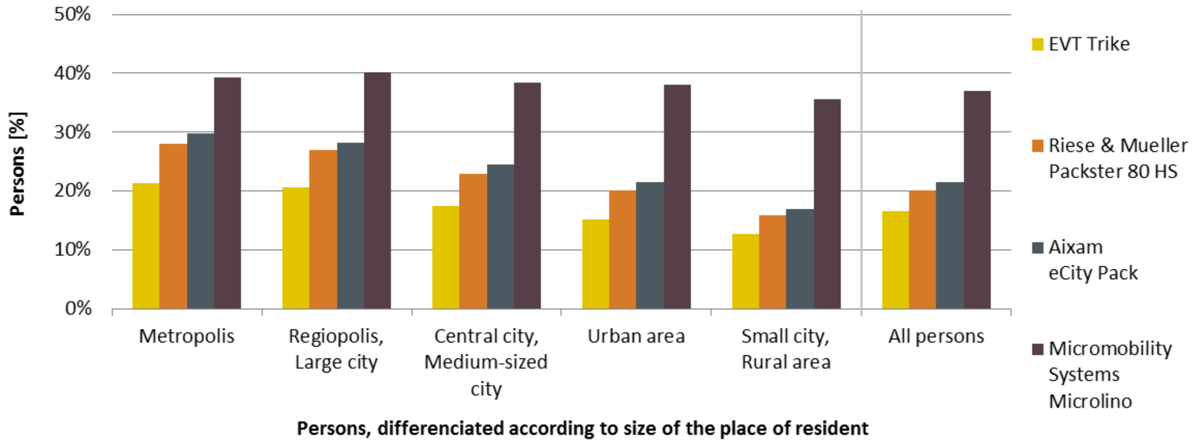

Figure 5: Relation between spartial structure and possibility of LEV use

7 Chances for Baden-Württemberg

7.1 Economic importance

In Baden-Württemberg, there is a world-leading cluster of automotive production with major manufacturers in the premium segment and major automotive suppliers. By contrast, LEVs do not appear to be in use or as a development or production location. In Germany as well as Baden-Württemberg there are currently only very few companies that develop LEVs and partly manufacture it in small batches.

Theoretically, the companies based in Baden-Württemberg cover the entire value chain - from vehicle development through production to sales and maintenance. In addition, there are complementary services such as sharing offers of cargo bikes. However, due to the low economic importance of this vehicle segment, a regional industry concentration is missing as a central feature of a differentiated economic cluster. [9]

The examples ELMOTO, Kyburz, the Microlino and the ELFIT show that a production in Germany or Baden-Württemberg is possible. However, it is only the assembly of the vehicle that is carried out here (or at the Kyburz in Switzerland). The purchased parts or components are preferably sourced from suppliers in the vicinity. Today it is not possible to produce a LEV with Baden-Württemberg or German parts alone. The battery cells for the electric drives are sourced from all the Asian companies surveyed, the same cells are used as for passenger cars or electronic consumer goods. For all other parts as well, manufacturers have the choice of purchasing from regional suppliers or, in particular, from Asian suppliers.

The interviewed manufacturers of LEVs assemble the vehicles in Germany and Baden-Württemberg. However, all the experts surveyed pointed out that high costs also lead to relatively high vehicle prices and that this is critical with regard to an expansion of sales. The price of the mentioned vehicles starts at about 5,000 €, comparable vehicles from Asian suppliers at about 2,000 €. Cheaper and thus economically even at lower vehicle prices is a highly automated production, which is, however, in the LEV sales figures today not feasible.

To what extent LEVs contribute to added value and employment in Baden-Württemberg today, can only be roughly estimated. For example, similar to vehicle-by-vehicle data, sales or employment for this vehicle class are not separately statistically recorded and published. Overall, rather marginal value creation and employment effects in Baden-Württemberg have to be assumed.

7.2 Traffic impact

LEVs have the potential to contribute to an improvement of the transport situation in cities in Baden-Württemberg. If securing individual mobility is paramount, replacement of combustion vehicles and their high energy efficiency, as well as the small footprint, make them an important segment in a sustainable vehicle fleet. The analysis of the MiD data shows that LEVs theoretically could take a significant share of traffic. Due to their vehicle characteristics, LEVs could be used in one-fifth to around half of all private-use roads, depending on the particular model in maximum. It is important to bear in mind, that the maximum substitution potential is only theoretical reachable but not realistic due to many limiting factors as comfort aspects or user behaviour.

Of course, the question arises for which modes of transport the various LEV concepts considered represent an alternative in each city. In cities, where the inhabitants often use the bicycle, e.g. Freiburg, Friedrichshafen and Karlsruhe, the EVT Trike represents a certain competitive situation with the bicycle. Of the residents of Friedrichshafen significantly more footpaths could be replaced by both the EVT Trike and the Microlino than in the other cities considered. From this it can be concluded that the use of transport in the respective cities also influences the potential for relocation, for example, the EVT Trike competes in Stuttgart less often by bicycle and more often by public transport than in the other cities.

7.3 Recommendation for action

A greater use of LEVs could only be achieved with considerable effort. In the expert discussions for the study, it became clear that LEVs can only achieve a significant share of the trips and traffic performance as well as a successfully establishment in the traffic system with clear support. The recommendations for action refer to a wide range of measures, which shows the complexity of this topic and the need for comprehensive trade.

One measure at the international level would be the inclusion of LEVs in the EU CO2 fleet targets. This would be an incentive for manufacturers to include these vehicles in the fleet. However, it also carries the risk that manufacturers will only use LEV credits to continue to offer heavy vehicles in the premium segment with internal combustion engines.

If the State of Baden-Württemberg would like to support LEVs, there are identified different measures to promote LEVs and make them more popular. One option might be to promote that LEVs can get public funding within the "BW e-Gutschein", a funding programme for electric vehicles by the Ministry of Transport Baden-Württemberg. Another aspect would be to expand the bicycle strategy of Baden-Württemberg to LEVs as well. In addition to that, the State of Baden-Württemberg should propose an adaption of legislation on Federal Level.

In addition to the State of Baden-Württemberg, e-mobil BW will also keep on working on LEVs. The study was just a first step for approaching this topic. Since 2010, e-mobil BW is coordinating the Cluster Electric Mobility South-West. Within this cluster more than 140 partners from industry and research are developing future mobility solutions. The study also illustrated possibilities to further research projects in the topic of LEVs, which will be discussed more in detail in the cluster and will be the starting point for following project activities.

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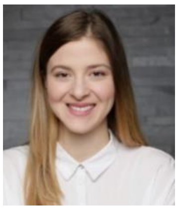	**Amelie Ewert** works as a research associate for the German Aerospace Center (DLR), Institute of Vehicle Concepts in Stuttgart, Germany since 2018. In her field of work she is responsible for user requirements and future perspectives of light vehicle concepts. Prior to her work she wrote her masters' thesis with DLR and gained experiences in the field of sustainable mobility in an international context at the German Development Corporation. She holds a bachelor degree in Geography and a master's degree in environmental management and urban planning in conurbations.
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