Empirical study of training needs for different occupational groups in the context of the increasing spread of electric vehicles

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***Abstract*—Dwindling fossil resources, avoidance of CO_2 emissions, and the reduction of noise emission in the cities are some of the reasons for the increasing sales numbers of alternative drive technologies worldwide. Besides the optimization of internal combustion engines, the automobile manufactures developed e.g. fuel cell vehicles, electric vehicles, and hybrid electric vehicles in recent years. Regarding the previously mentioned global goals, this can be valuated as a generally positive development. However, the changes, tendencies and developments in the automobile sector also lead to new challenges. One challenge is the qualification of employees for working on electric vehicles and hybrid electric vehicles. This paper presents the training needs for different occupational groups based on an empirical study with 306 employees and expert interviews. The interviewees are firefighters, motor mechanics, and employees of breakdown and towing services. Based on the results, this paper shows some recommendations for the development of future training programs with regard to the topic electromobility.**

Keywords—training needs; further education; electric vehicles; empiricial study; lifelong learning

I. INTRODUCTION

According to the "Global EV Outlook 2016" [1] of the International Energy Agency, 1.26 million electric vehicles (EVs) were on the streets worldwide at the end of 2015. For example, China strives for the goal to have 4.6 million EVs on the streets in 2020 whereas the target mark of the USA is 1.2 million EVs in 2020 [1]. This development leads to new challenges in the training sector. Aside from motor mechanics, there are many occupational groups, which are affected in their everyday working life by the growing spread of EVs, hybrid electric vehicles (HEVs), and fuel cell vehicles (FEVs). Firefighters need to know how they can handle burning EVs or how they can extricate trapped accident victims. Rescue teams need to know how they can help injured people of an accident with EVs and employees of towing services and breakdown services need to know how they can tow EVs without damaging components of the high voltage system.

In [2], the German Federal Ministry of Education and Research emphasizes that qualified and motivated professionals are an important component for a future mobility with EVs and HEVs. Moreover, the authors underline the importance of inter-company trainings for professionals and the cooperation between the academic sector and the industry. For the clarification of the number of potential occupational groups, some facts are shown in the following.

In 2014, 462,000 people were employed in the area of vehicle repair services in Germany [3] and approximately 739,000 automobile technicians and mechanics in the USA [4]. In addition, 30,796 professional firefighters and 998,682 volunteer firefighters worked at German fire departments in 2013 [5]. Compared to Germany, the USA had 346,150 professional firefighters and 788,250 volunteer firefighters in 2014 [6] . The data of these two occupational groups illustrates how many people are likely to get in contact with EVs in their everyday working life. In addition, there are many other occupational groups as well. For example, if an EV or HEV is involved in an accident with personal injury, paramedics are further professionals who need special training programs in the context of this new kind of hazard.

II. GOAL OF THIS PAPER

The previous section presents selected forecasts for the future development of the mobility sector and potential occupational groups. Those facts clarify that a great number of professionals exists, which have the possibility of getting in contact with EVs and HEVs in their working life. Hence, these employees need a specialized training program for working on vehicles with alternative fuels (especially EVs and HEVs).

Therefore, a survey with 306 professionals in Germany in 2016 analyzed the training needs in the context of the growing spread of EVs and HEVs for different occupational groups. The interviewees are working in the area of vehicle repair services, fire departments or towing and breakdown services, see Fig 1. The main reason for this selection is that the mentioned occupational groups play an important part for the satisfaction of the owners of EVs and HEVs during the use phase. Thus, other professions along the value chain are not included in this empirical study. Nevertheless, the empirical analysis of other occupational group is also important and can be investigated in upcoming research projects.

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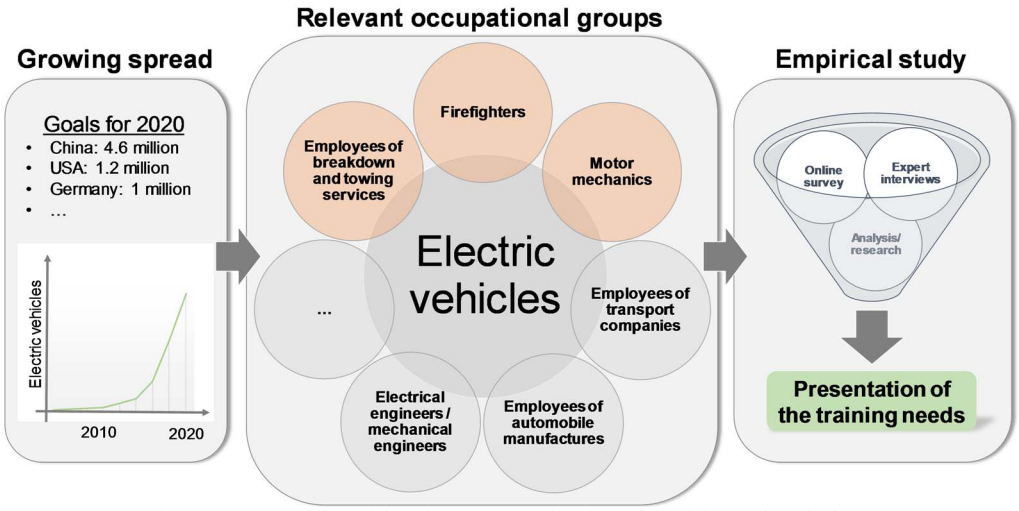


Fig. 1. Presentation of the relevant occupational groups and the used methodology

The empirical study, which is presented in this paper, is part of the research project "EmoTal – User Centered Electric Mobility Wuppertal" [7], which is funded by the German Federal Ministry of Education and Research since August 2014. The survey results will be used for the further development of an adaptive e-learning platform [8] in an industrial cooperation with the German Association for Technical Inspection ("TÜV NORD Bildung GmbH & Co. KG").

The empirical investigation involves interviews with experts from the area of motor vehicle services, fire departments, and breakdown and towing services to verify the survey results and to get more information about the training needs, see Fig. 1. Based on the results of the empirical study, the paper presents recommendations to improve existing training programs as well as to develop new training programs, which take the results of the survey and of the expert interviews into account.

Before the presentation of the empirical investigation, the following chapters show current training programs and the potential health risk by working on EVs and HEVs.

III. Current Training Programs

The topic electromobility is content of many research projects and science publications regarding to the education sector. Furthermore, different companies have developed specialized training programs. Nevertheless, there are urgent training needs in the context of the growing spread of EVs and HEVs. Hence, this section presents some selected examples to give an overview of the current state and to emphasize the training requirements.

The project "NquE – Networking for Electric Mobility Education and Training" [9] has identified 33 academic courses and 18 training programs for vocational education (e.g. professionals or apprentice) in Germany. These results show that the number of programs in the academic sector is greater compared to the program varieties for vocational education.

The past research activities of the project "EmoTal" leads to similar results. For example, in [10] and [11] the authors highlight that there is already a great educational offer in the academic sector in Germany and that the most of the analyzed projects are not for professionals.

In the report "Needs Assessment for Alternative Fuel Vehicle Training in California" [12], which was prepared by the California Center for Sustainable Energy and the California Clean Cities Coalitions, the authors presents the training needs for fire departments and fleet managers in the United States of America. One finding is, that there is a great potential to improve and to increase the existing training programs.

Hence, the next two chapters deal with current training programs for academic education and vocational education as well as further education to show the current status.

A. Academic Education

The authors of [13] present a new master degree on "Intelligent Electric Vehicles" at the University of Lille in France. Beside electrical engineering, this program includes mechanical engineering and automatic control. For the enhancement of the knowledge transfer, the program use a project based philosophy.

In [14], the authors clarify the new challenges for the Slovak education sector in the context of electromobility. They emphasize that education programs for the topic electromobility need high investments. Based on this, they propose a cooperation between universities and industry as a good solution for the development of specialized training programs. One further finding of this paper is that the knowledge of the employees is a very important key factor for the future of the automobile sector and especially for EVs.

For a better understanding, how an EV and HEV works, the authors of [15] developed a small-scale HEV. This HEV has all necessary key components of a real HEV. Hence, the students have the possibility to work under almost real conditions. For example, this test bench allows the exchange of components or the implementation of different control methodologies. Similar to [13], the authors also highlights the advantages of practical learning under almost real conditions compared to pure theoretical education.

A further educational offer, which uses a problem and project based learning approach in the context of EVs, is presented in [16]. This training program was developed for students at the Université de Sherbrooke in Canada. This program includes electrical engineering, software engineering, and mechanical engineering. The results of the already developed prototypes show that the used didactic method is a good preparation for students for working in the industry.

More training programs for academic education, which deal with the topic electromobility, are e.g. [17], [18], and [19].

For the satisfaction of the owners of EVs or HEVs and for achieving the defined goals (e.g. 1 million EVs in 2020 in Germany), professionals with a specialized qualification for working on EVs and HEVs are very important. Especially the service sector (motor vehicle service etc.) plays an important role for the satisfaction of car owners and has a not negligible influence on the purchase decision of potential buyers of EVs or HEVs.

The next chapter illustrates the current state of training programs for vocational education and further education as well as lifelong learning for professionals.

B. Vocational Education and Further Education

The previous chapter clarifies that there is a great offer of specialized academic programs for the qualification for the topic electromobility. The research results of [10] and [11] underline the backlog in vocational education and further education.

The topic electromobility is content of the training plan for future automotive mechanics in Germany since 2013 [20]. The apprentices learn e.g. the function of the different components of EVs and HEVs and the cause-effect relationship between the several components (relays, inverter etc.) respectively between the several subsystems (high-voltage system, thermal management, control electronics etc.). After finishing this training program, they are able to test the different components, to find electronic errors, and to exchange defect components. Nevertheless, professionals, who started their vocational training before June 2013, need a specialized training program as well.

One of these programs is the "Alternative Fuel Vehicle (AFV) Safety training Program" [21] of the National Fire Protection Association (NFPA) in the United States of America. The target group of this program are firefighters and further emergency responders in the United States of America. The NFPA uses different didactic methods (videos, simulations, 3D interactive environments etc.) to impart the knowledge to the participants.

The training programs of the "TÜV NORD Bildung GmbH & Co. KG" (Germany) are e.g. for the target groups firefighter, motor mechanics, and employees of towing and breakdown services [22]. For example, the program for motor mechanics contains, among others, lectures, practical instructions, and practical exercises. Hence, the participants have the opportunity to learn under real conditions.

Further training programs in the United States of America are offered by the National Alternative Fuels Training Consortium (NAFTC). These programs are part of a project of the West Virginia University and were developed in 1992. For example, the so-called "Advanced Electric Drive Vehicle Education Program" [23], which is funded by the U.S. Department of Energy, contains different qualification levels and learning objects depending on the respective occupation. The target groups are e.g. first responder, automotive technicians, or trainers.

The "ZF Friedrichshafen AG" (Germany) offers training programs for different applications and occupational groups [24]. The lowest qualification level contains non-electrical engineering work like the oil change at an HEV. Compared to this, the training program with the highest qualification level is for the qualification for working on an activated high-voltage system of EVs and HEVs (e.g. exchange of components).

The above-mentioned programs illustrate that there is already a large number of qualification measures for working on EVs or HEVs. Nonetheless, it is indispensable to know the learning content, which the participants really need in their everyday working life.

The survey presented in this paper has the goal to identify the preferred didactic methods of the potential participants (practical exercises, interactive exercises etc.). Moreover, some experiences and results from past programs as well as recommendations for the improvement and enhancement of future training programs are shown.

IV. New Type of Occupational Risk

The authors of [25] conclude that a reliable statement, whether an EV is more dangerous than a conventional car or vice versa, is not possible. This conclusion is based on the manageable number of EVs and HEVs compared to conventional cars (e.g. with internal combustion engine).

However, it can be stated that the several components of EVs and HEVs lead to a change of the kind of hazard in the everyday working life of different professionals. Therefore, the next sections illustrate the general new hazard potential that is based on the greater voltage level compared to vehicles with internal combustion engine. Furthermore, the occupational risks for firefighters, employees of breakdown and towing services, and motor mechanics are clarified.

A. High-voltage System

In common vehicles, the voltage of the integrated battery is generally between 12 V DC and 48 V DC [26]. These batteries deliver the energy e.g. for the onboard electronic (navigation system, air-condition etc.) and the main energy source for the propulsion of conventional vehicles is gasoline. EVs obtain their electric operating energy from a high-voltage battery. Hence, energy storage of EVs operate with higher voltages and currents. For example, the voltage of the high-voltage battery of the "Nissan Leaf" is 360 V DC [27] and therefore significantly higher compared to the previously mentioned battery voltage of conventional cars.

According to definition [28] of the Society of Automotive Engineers (SAE) and to the definition [29] of the Economic Commission for Europe of the United Nations (UN/ECE) the range of high-voltage systems is for AC between 30 V and 1000 V and for DC between 60 V and 1500 V. Thus,

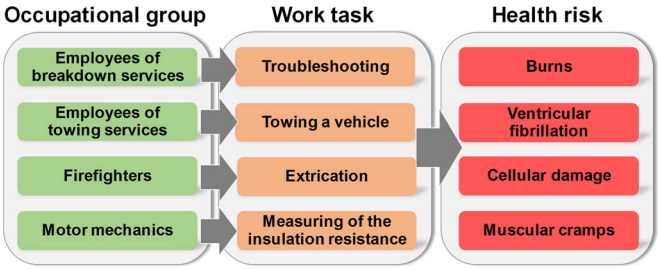


Fig. 2. Potential health risk by working at electric vehicles

professionals, who work at a high-voltage system, must comply with safety regulations. Besides wearing personal protective equipment (PPE), the professionals need to know how safety systems work, like the service disconnect switch of an EV. The disregard of the five safety rules (isolate, safeguard against reconnection etc.) could mean a high health risk for professionals [30]. Fig. 2 presents some examples of the health risk for the different occupational groups (burns, ventricular fibrillation etc.).

The next chapter presents the new kind of hazard depending on the different occupational groups respectively on their common work steps.

B. Occupational Risk

Electrical accidents and fires caused by an electrical failure are not a new topic for firefighters. The National Fire Protection Association (NFPA) of the United States of America presents in its repot "Electrical Fires" [31] that between 2010 and 2014 45,210 home structure fires and 16,070 non-home structures fires are caused by an electrical failure. Hence, firefighters already know the general hazard of electrical systems. The main reasons for these fires were an electrical failure at the electrical distribution, lightning, and power transfer.

Compared to the already existing knowledge in the handling of fires based on electrical failure, the electric systems of EVs and HEVs are different. For example, firefighters need to know how they can extricate trapped accident victims. Therefore, they need to know the position of the different components (high-voltage cable or battery, service disconnect etc.). Otherwise, there is the risk that firefighters e.g. can cut an active high-voltage cable (see Fig. 3) and an electrical arc could occur.

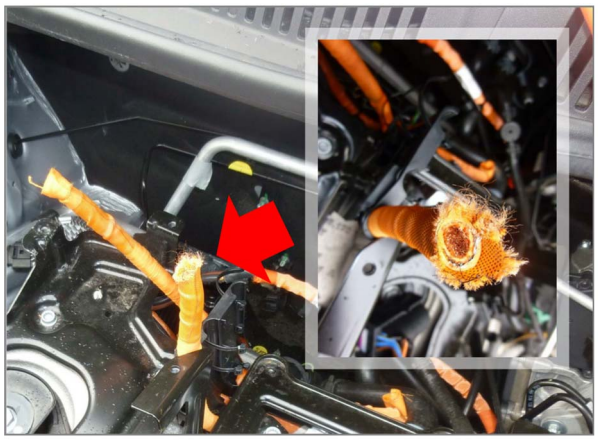


Fig. 3. Defective high voltage cable

In cooperation with the United States Department of Energy, the NFPA published the report "Alternative Fuel Vehicle Safety Summit" [32] in August 2016. Beside the presentation of the needs of specialized training programs, the report clarifies the new kind of hazard compared to vehicles with an internal combustion engine. One highlighted research gap is the "lithium ion battery fire suppression effectiveness".

In relation to necessary post event handlings, the authors underline that employees of towing services need to know the potential hazards as well. For the future, the authors propose a national data collection of emergency events involving an AFV (e.g EV or HEV) to learn from past events [32].

Furthermore, the National Fire Research Foundation released the report [33] in 2013. This report shows the best practices for emergency response to incidents involving EVs battery hazards. This report is relevant e.g. for firefighters to learn the different kind of hazard of EVs or HEVs (electrical, respiratory etc.). One important finding is that after visible flames were clearly extinguished, the temperature inside the batteries can be high enough to reinflame the fire (keyword: thermal runaway).

Hence, it can be stated that vehicle fires of EVs required a great volume of water to extinguish the fire in comparison to conventional cars (see also [25]). The main reason for this is the cool down process of the battery to avoid a thermal runaway. In one case, the EV reinflame 22 hours after the extinguishing process [33]. This is an important information for motor mechanics and employees of breakdown and towing services as well.

For firefighters or further employees of rescue teams, it is indispensable to study the respective emergency response guide of the vehicle, which is involved in an accident. These guides describe e.g. the position of the components (inverter, high-voltage etc.) and the necessary work steps to deactivate the high-voltage system [34].

In the context of emergency response guides the "Crash Recovery System" [35] of Moditech Rescue Solutions B.V. (Netherlands) is, among others, a promising system to improve rescue operations. This system is available for many operating systems (Android, Windows etc.) and contains a database with emergency response guides of several automobile manufactures. Hence, firefighters are able to retrieve the necessary data on their mobile device directly at the accident site.

In the report "Training for work on vehicles with high voltage systems" [30], the authors presents the different electrical hazards in context of employees in the area of motor vehicle service (e.g. motor mechanics) and employees of automobile manufactures (e.g. electrical engineers). Moreover, this report gives recommendations for the scope of the learning content and duration of specialized training programs for working on EVs or HEVs depending of the prior knowledge of the employees. For example, a participant without any knowledge about electrical engineering need significant more content with regard to principles of electrical engineering compared to an electrical engineer.

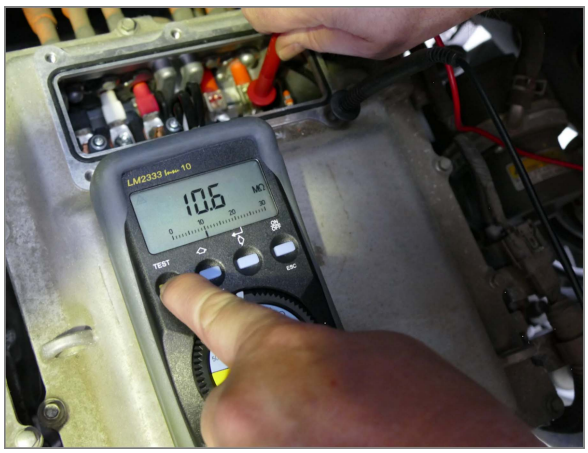


Fig. 4. Measurement of the insulation resistant at an inverter

The measuring of the insulation resistance of different components, especially of the high-voltage cable, is part of the everyday work of a motor mechanics (see Fig 4.).

In [36], the NAFTC presents information for employees of towing services in the context of vehicles with alternative fuels. The authors highlight e.g. that EVs are extremely quiet. Hence, the professionals need to check, whether the vehicle respectively the high-voltage system is on or off.

Furthermore, emergency response guides contain e.g. information about the position of the high-voltage battery and appropriate lift areas. An important point is that firefighters must inform employees of towing services about the already performed working steps.

As already mentioned, the training needs are not limited to these occupational groups. There are many other employees, who need specialized training programs like engineers in the battery production, employees of wracking services, or service technicians of transport companies, which have e.g. electrical buses.

V. Empirical Study

The findings of the online survey includes the opinions of 306 participants. 148 of them are firefighters, 96 are motor mechanics, and 62 work in the area of breakdown and towing services. Additionally, three experts are interviewed to complement the results of the online survey and to give reliable recommendations.

The aim of this study is to identify the training needs, to learn from experience gained, and to detect the preferred didactic methods and learning contents. These results are important for the optimization of existing programs as well as for the design of new qualification measures for working on EVs and HEVs.

A. General Information

Before the presentation of the survey, some general statistic information are shown in the following. For example, one firefighter is female and 147 firefighters are male, see Tab. I. The arithmetic mean of the age of the firefighters is 36.53 and the median amounts 35. The youngest firefighter was 20 years old and the oldest firefighter 63 years old. Compared to the firefighters, eight motor mechanics are female and 88 motor mechanics are male. The arithmetic mean of the age of the motor mechanics is 48.91 and the median is 50. The youngest motor mechanic was 27 years old and the oldest motor mechanic was 77 years old. These data clarify, that the interviewed motor mechanics are generally older than the firefighters. The last interviewed occupational group are the employees of breakdown and towing services. Four employees of them are female and 58 employees of them are male. 45.15 years is the arithmetic mean of this group. The median of the age of the employees of breakdown and towing services is 45. The youngest employee is 27 years old and the oldest employee 58 years old.

The presentation of the results of the online survey can be divided into the topics “personal attitude”, “current training offers”, and “working on electric vehicles”. The full survey includes more topics like “information about the company”. Nevertheless, the most relevant topics in context of the focus of this paper are the three previously mentioned topics. Hence, the results of the other topics are not included in this paper.

The topic “personal attitude” is important to get some information about the personal attitude to electromobility of the participants. Thus, an identification of correlations between the personal interest for electromobility and the personal view, whether training programs are necessary, is possible. The second topic “current training offers” delivers findings about current training programs and gives some information about the current qualification level of the interviewees and their colleagues. A further important detail of this topic is the personal willingness for the participation in training programs for working on EVs. The last topic “working on electric vehicles” shows the level of experience of the difference interviewees for working on EVs. Moreover, the occupational risk by working on EVs and the necessary requirements for working on EVs are shown.

At this point, it must be stated, that the survey contains besides closed questions (multiple choice) a large number of open questions. The providing of open questions is necessary to get more personal information respectively more personal opinions of the interviewees in context of electric vehicles. As mentioned before, there are already many training programs for working on EVs. However, for a successful and sustainable training program it is very important to include the opinions of the potential participants. Furthermore, it is very useful to know, what the participants really need in their everyday working life.

TABLE I. General Statistic Information of the Survey (Absolute Numbers)

	Gender		Age			
Test Group	***Female***	***Male***	***Arithmetic mean***	***Median***	***Minimum***	***Maximum***
Firefighters	1	147	36,53	35	20	63
Motor mechanics	8	88	48,91	50	24	77
Breakdown/towing servics	4	58	45,15	45	27	58

TABLE II. RESULTS OF THE TOPIC "PERSONAL ATTITUDE" (IN PERCENT)

	Firefighters					Motor mechanics					Breakdown/towing services				
Coding	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Personal interest for electromobility	36,49	27,70	16,89	14,19	4,73	41,67	4,17	41,67	3,12	9,38	20,97	3,23	59,68	3,23	12,90
Willingness for buying an EV	24,32	73,65	2,03			12,50	3,12	20,83	26,04	37,50	3,23	4,84	30,65	22,58	38,71

Based on the combination of closed questions and open questions a grouping of the answers respectively the implementation of a coding is indispensable. Hence, it is possible that the number of used codes (e.g. 1 to 6) vary between the different questions and occupational groups.

B. Results of the Topic "Personal Attitude"

The personal attitude is very important to identify correlations between the personal attitude and the other topics as well as other questions. Therefore, Tab. II presents some selected results of the topic "personal attitude".

A share of 36.49% of the firefighters have a private and an occupational interest for the topic electromobility (coding=1). In addition, 27.70% have only a private interest (coding=2) and 16.89% have only an occupational interest (coding=3). A share of 14.19% of the interviewed firefighters did not deal with these topic in the past (coding=4) and 4.73% have no interest for EVs (coding=5).

In comparison to the firefighters, motor mechanics have a greater personal and occupational interest (41.67%). An interest finding is that motor mechanics have a very small private interest (4.17 %). Therefore, it can be stated that the most of the motor mechanics (41.67%) only deal with this topic in their work life. Furthermore, the disinterest for the topic electromobility is greater (9.38%) compared to firefighters.

The results of the employees of breakdown and towing services are completely different compared to firefighters and motor mechanics. For example, only 20.97% of these employees have a private and an occupational interest. Additionally, the private interest is very low (3.23%).

One interesting finding is that 56.98% of the employees of breakdown and towing services only deal with the topic electromobility in the context of their everyday working life. This result indicates that these employees already knows about the importance of an in-depth knowledge for working on EVs, thus they are dealing with this topic.

The next question is an open question. Therefore, the coding for the three occupational groups are different. On the one hand, approximately one quarter (24.32%) of the interviewed firefighters have no interested in buying an EV (coding=1). On the other hand, 73.65 % are interested in buying an EV (coding=2) and 2.03% have already an EV (coding=3).

A share of 12.50% of the motor mechanics have already an EV (coding=1) and 3.12% would like to buy an EV in the course of this year (coding= 2). The share of motor mechanics, who would like to buy an EV in the next two to five years (coding= 3), is 20.83% and of motor mechanics, who would like to buy an EV in the next five to ten years (coding= 4), is 26.04%. One interest finding is that 37.50% have no interest in buying an EV (coding=5).

Compared to the motor mechanics, only 3.23% of the employees of breakdown and towing services have already an EV. The further results of this group are very similar to the results of the motor mechanics. It can be noted, that 38.71% of this occupational group have no interest in buying an EV. This is the highest disinterest of all three occupational groups.

C. Results of the Topic "Current Training Offers"

The aim of this chapter is the identification of the current qualification level, of the current training offers, and of the willingness for the participation in training programs. The first question deals with the personal qualification level of the participants for working on EVs. As shown in Tab. III, a share of 63.43% of the firefighters think that they are sufficiently qualified for rescue operations at accident-damaged EVs (coding=1). In addition, 8.21% of the firefighters have the opinion that there is no need for specialized training program for working on EVs.

Approximately the half of the motor mechanics (56.18%) is already qualified for working on EVs (coding=1) and nearly one fifth of the motor mechanics (21.35%) are not qualified based on an insufficient educational offer (coding=2). Moreover, 16.85% thinks that there is currently no training need for the topic electromobility (coding=3).

In context of electromobility, the most qualified occupational group are the employees of breakdown and towing services. 83.05% of them are already qualified for working on EVs (coding=1) and only 6.78% answered that they are not qualified because of an insufficient education offer (coding=2). A further interesting finding is the fact that only one employee (1.69%) of the interviewees of breakdown and towing services have the opinion that there is no training need based on the growing spread of EVs. Thus, the majority of the interviewees of this occupational group are qualified for working on EVs and have a high awareness for the necessary training needs.

TABLE III. RESULTS OF THE TOPIC "CURRENT TRAINING OFFERS" (IN PERCENT)

	Firefighters						Motor mechanics					Breakdown/towing services				
Coding	*1*	*2*	*3*	*4*	*5*	*6*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Personal qualification level	63,43	1,49	3,73	11,94	11,19	8,21	56,18	21,35	16,85	3,37	2,25	83,05	6,78	5,08	3,39	1,69
Qualification level of the team	35,86	10,34	11,72	3,45	4,14	34,48	36,46	63,54				9,84	90,16			
Local training offers	40,82	48,98	10,20				56,25	12,50	31,25			64,52	14,52	20,97		
Willingness for training programs	13,19	86,81					60,00	17,50	22,50			86,36	4,55	9,09		

Besides the knowledge about the personal qualification level, it is interesting to know the qualification level of a whole fire department or of a whole car repair shop, see Tab. III. A share of 35.86% of the interviewed firefighters indicates that they have qualified colleagues at their fire department (coding=1). In addition, 11.72% have the opinion, that a specialist for the topic electromobility is not necessary (coding=3) and 34.48% think, there is no training need. Compared to the question regarding to personal qualification level, this means that many firefighters are qualified because of a personal interest for this topic.

The interviewed motor mechanics answered, that 63.54% of them have already qualified colleagues in their team (coding=2). On the other side, there is more than one third of the participants (36.46%), who have no colleagues, which are qualified for working on EVs (coding=1). On the one hand, it can be stated, that many motor mechanics are already qualified for the topic electromobility. On the other hand, there is great number of motor mechanics, which are not qualified for working on EVs. The median of the age of the asked motor mechanics is 50 years. Hence, the most of them are professionals with a great work experience and they already finished there apprenticeship a long time ago. Therefore, the development of a further training program for professionals is very important.

The personal qualification level of the employees of breakdown and towing services regarding to working on EVs is very high. A similar result shows the investigation of the qualification level of the whole team respectively of the whole company. Already 90.16% of the interviewees have qualified colleagues for working on EVs (coding=2). This means, that the sector of breakdown and towing services have an overall high qualification level in relation to electromobility. Working on an electrical system is a complete new task for these employees. For example, firefighters have already gained experience with electrical accidents and fires in the past, which were caused by an electrical failure. Therefore, employees of breakdown and towing services have a higher awareness for the new type of hazard. In relation to current local training offers for the qualification for working on EVs, the sector of breakdown and towing services has with a share of 64.52% the highest offer (coding=1). This finding underlines the previous assessment, that this sector is already well qualified and the employees have a high awareness for this topic. Nevertheless, 14.52% of the interviewed employees of breakdown and towing services stated that there is currently no specialized training program (coding=2) and approximately one fifth (20.97%) have no information about local training programs (coding=3). The results of the interviewed motor mechanics are approximately similar regarding to the topic "local training offers". One big difference is the great disinformation about local training programs for working on EVs (31.25%). This is an important finding, which highlights that the framework for training programs for working on EVs need to be improved. The improvement contains, among others, the distribution of information about qualification measures for the topic electromobility at schools, colleges, and universities.

In addition, approximately the half of the interviewed firefighters (48.98%) stated, that there are no local training programs. Hence, there is a great need of specialized training programs, especially in relation the personal qualification level (63.43%) and qualification level of the team (35.86%), see Tab. III. The willingness for the participation in an education program for the qualification for working on EVs is in all three occupational groups high. The majority of the firefighters (86.81%; coding=2), of the motor mechanics (60.00%; coding=1), and of the employees of breakdown and towing services (86.36%; coding=1) are interested in specialized training programs. Therefore, the development of qualification programs for the topic electromobility can be a promising business model for training companies or universities (e.g. [23]).

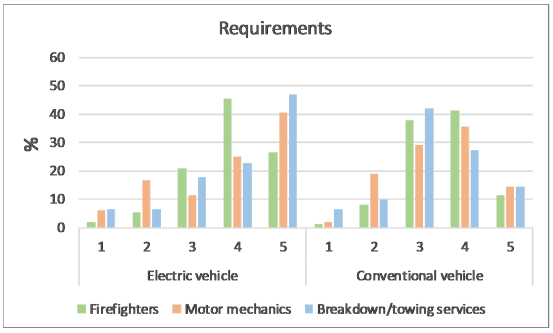
D. Results of the Topic "Working on Electric Vehicles"

Tab. IV shows the current experience of the interviewees for working on EVs as well as their assessment for the necessary requirements and the occupational risk based on the new type of hazard. The majority of the firefighters (87.16%) stated that they did not participate in rescue measures for accident-damaged EVs (coding=1) up to now. Only 8.78% of the interviewed firefighters were already involved in at least one rescue measure for an accident-damaged EV (coding=2) and 4.05% answered, that they already gained experience at more than one accident with the involvement of an EV (coding=3). Compared to firefighters, more than the half of the interviewed motor mechanics (52.75%) and only 17.74% of the employees of breakdown and towing services have already worked at EVs (coding=1). The great experience of motor mechanics is a result of many different services for EVs (diagnostic, inspection etc.), which are offered by car workshops. For example, EVs need to be checked regularly without an accident. Therefore, the lack of experience of firefighters and employees of breakdown and towing services is a result of the current low number of EVs on the streets worldwide. However, the sales volume of EVs will increase in the future and thus, the number of damaged EVs will increase as well.

The last results of the online survey, which are presented in this paper, are the assessment of the necessary requirements and the occupational risk. The coding for these two topics is simpler compared to the others. The value "1" means "very low" and "5" means "very high", see Fig. 5. More than the half of all three interviewed occupational groups think, that the necessary requirements for working on EVs are high (coding=4) or very high (coding=5). This means in detail, 26.35% of the firefighters, 40.62% of the motor mechanics, and 46.77% of the employees of breakdown and towing services think, that the

TABLE IV. RESULTS OF THE TOPIC "WORKING ON ELECTRIC VEHICLES" (IN PERCENT)

	Firefighters					Motor mechanics					Breakdown/towing services				
Coding	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Experience	87,16	8,78	4,05			52,75	47,25				17,74	82,26			
Necessary Requirements	2,03	5,41	20,95	45,27	26,35	6,25	16,67	11,46	25,00	40,62	6,45	6,45	17,74	22,58	46,77
Occupational risk	1,35	12,84	39,86	31,08	14,86	8,33	18,75	15,62	28,12	29,17	4,84	9,68	22,58	9,68	53,23



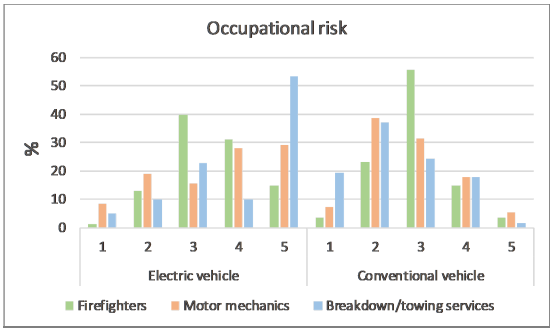


Fig. 5. Necessary requirements (left) and cccupational risk (right) for the selected professionals; (1: "very low"; 5: "very high")

necessary requirements are very high. For the clarification of the requirements compared to conventional cars (e.g. with an internal combustion engine), Fig. 5 illustrates the direct comparison. For example, the arithmetic mean for employees of breakdown and towing services is for EVs 3.97 and for conventional cars 3.34. This underlines once again, this occupational group have a high awareness for the necessary requirements for working on EVs. A similar result is presented for the assessment of the occupational risk, see Tab. IV and Fig. 5. The arithmetic average of the risk assessment of all three occupational groups for working on EVs is higher compared to conventional vehicles. The arithmetic averages of firefighters are 3.45 for EVs and 2.92 for conventional cars. In addition, the arithmetic averages of motor mechanics are 3.51 for EVs and 2.75 for conventional cars. The comparison between the several vehicle types has the greatest difference at the risk assessment of the employees of breakdown and towing services: 3.97 for EVs and 2.45 for conventional cars.

E. Results of the Expert Interviews

The expert for firefighters think that there is a new type of risk by working on EVs and that an integration of the topic electromobility in the basic education of firefighters is a meaningful measure, see Tab. V. According to the statement of this expert, the integration of practical exercises in the training (e.g. at a burning EV) is very important for firefighters. Additionally, the expert for motor mechanics highlights, that the qualification of the employees of independent car workshops is very important, because authorized workshops are qualified by the several manufactures. Furthermore, he states that the qualification for working on EVs is essential for the future career opportunities in the context of the growing spread of EVs. Both experts underline, that a standardized regulation is a key factor for a successfully qualification of the employees. Furthermore, the expert for the sector breakdown and towing services emphasizes that the employees of this sector have a higher risk awareness and have a great respect for the high-voltage battery. Therefore, he confirms the results from the online survey.

VI. CONCLUSION

The topic electromobility is becoming more and more important in the educational sector. This results from the growing spread of EVs. There already exist many training programs for working on EVs. Nevertheless, the training needs are still great. This assessment is underlined by the results of the empirical study (online survey and expert interviews). The study shows for example that the interviewed motor mechanics have the lowest qualification level for working on EVs. Another result from the study is that the training offers for firefighters need to be expanded. They stated that they prefer practical exercises at EVs. The interviewed employees of breakdown and towing services are already well qualified and have the highest awareness for the new hazard potential that is implicated in EVs. According to the statement of the expert of this sector, this awareness depends on the great respect for the high-voltage battery. A further recommendation resulting from the survey is the development of regulations respectively the revision of existing regulations to improve the qualification for the topic electromobility. The cooperation between training companies and automobile manufactures is another recommendation for the development of a successful and sustainable training program, especially in the context of this new technology. Furthermore, the development of a novel training program or the improvement of an existing program for working on EVs is a future-oriented business model. Concluding it can be stated, that this empirical investigation is not representative for all regions worldwide and all potential professionals. However, the results of this paper are based on a detailed research of current training programs and on the statements and assessments of 306 interviewees as well as expert interviews. Therefore, this paper is a promising groundwork for the development of future training programs.

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TABLE V. MOST IMPORTANT STATEMENTS OF THE EXPERTS

Firefighters	Motor mechanics	Breakdown/towing services
"New type of risk…"	"Success of EVs depends on future battery technology…"	"Slow development of the sales volume of EVs…"
"Integration of the topic EV in the basic education…"	"Motor mechanics have a low risk awareness…"	"Existing high risk awareness…"
"More information are needed (e.g. brochures)…"	"Great need for training programs (e.g. independent garages)…"	"Training for working on EVs is very important…"
"Existing high risk awareness…"	"Training is important for career opportunities…"	"High-voltage battery is very dangerous…"
"There are no regulations…"	"Training is very important for further education…"	"Special personal protection equipment is needed…"
"Special personal protection equipment is needed…"	"Revision of regulations…"	"Isolated lashing straps are needed…"

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