LOGI – Scientific Journal on Transport and Logistics
Vol. 10 No. 2 2019 DOI: 10.2478/logi-2019-0012

Development of Electromobility in Terms of Freight Transport

Václav Cempírek[1*], Iwona Rybicka[2] and Ivica Ljubaj[3]

[1]*College of Logistics, o.p.s., Palackého 25, CZ 750 02 Přerov, Czech Republic; Email: vaclav.cempirek@vslg.cz*
[2]*Lublin University of Technology, Faculty of Mechanical Engineering, Institute of Transport, Combustion Engines and Ecology, Nadbystrzycka Street 36, 20-618 Lublin, Poland; Email: stasys.steisunas@vgtu.lt, gediminas.vaiciunas@vgtu.lt*
[3]*University of Zagreb, Faculty of Transport and Traffic Sciences, Department of Railway Transport, ZUK Borongaj, Borongajska cesta 83a, 10000 Zagreb, Croatia; Email: iljubaj@fpz.hr*

***Corresponding Author:** Václav Cempírek

Abstract: The paper deals with specific aspects regarding the current development trends of electromobility in the context of road freight transport. The current system of electric vehicles for road freight transport and the relevant investigations are based on the experience with operating trolleybuses, which have the same power supply of traction motors from the overhead traction line by means of traction pantographs. As for the future, it has not been decided yet which electromobility-related power system will be used in practice, whether the supply of electric motors from traction lines or battery packs. In the introductory chapters, the manuscript discusses the fundamental information regarding the electromobility, current projects dealing with this issue, individual aspects and attributes related to these existing power systems, and their advantages and disadvantages in terms of their usage. In the most important part of the manuscript, the adequate evaluation is performed, as well as very recommendations for future research in a given topic are proposed.

Keywords: Electromobility, greenhouse gas, induction power supply, electric current collector

1. Introduction and Literature Review

The rising transport volumes in the world cause multiple negative impacts on the environment; one of them is represented by air pollution problem, which is generated by burning fossil fuels, agricultural activities, exhausts from factories and several other activities. Global climate changing is very topical issue, since the Earth surface temperature and ambient air temperature have been reaching higher values even more intense and more frequent [1]. Global warming and air pollution are largely caused by greenhouse gases (GHG), which are emitted by many anthropological activities; like industry, construction, transport operation, etc.

In the international climate protection agreements in Paris from 2015, all the signing parties agreed on a voluntary commitment to limit the global warming to 1.5 degrees Celsius. The European Union committed to diminish the greenhouse gas emissions by 40 % until 2030. In the EU climate and energy package 2020, the EU member states agreed on the increase of the share of renewable energies up to 20 % of the total energy usage in 2008 [2].

For example, in Germany, the transportation sector accounts for almost of 18% of the total greenhouse gas emission values. Hence, transport is the third largest generator of emissions in this country. Moreover, up to 96 % of the emissions from the transportation sector result from road transportation systems [3]. The annual survey of the European Environment Agency shows that compared to other European countries, a number of cities in Germany exceed the NO_2 limitations of 40 $\mu g/m^3$, as depicted in Figure 1 [4]. This emphasizes the urgent need of action that Germany has to deal with on regional level to reach the desired emission abatement.

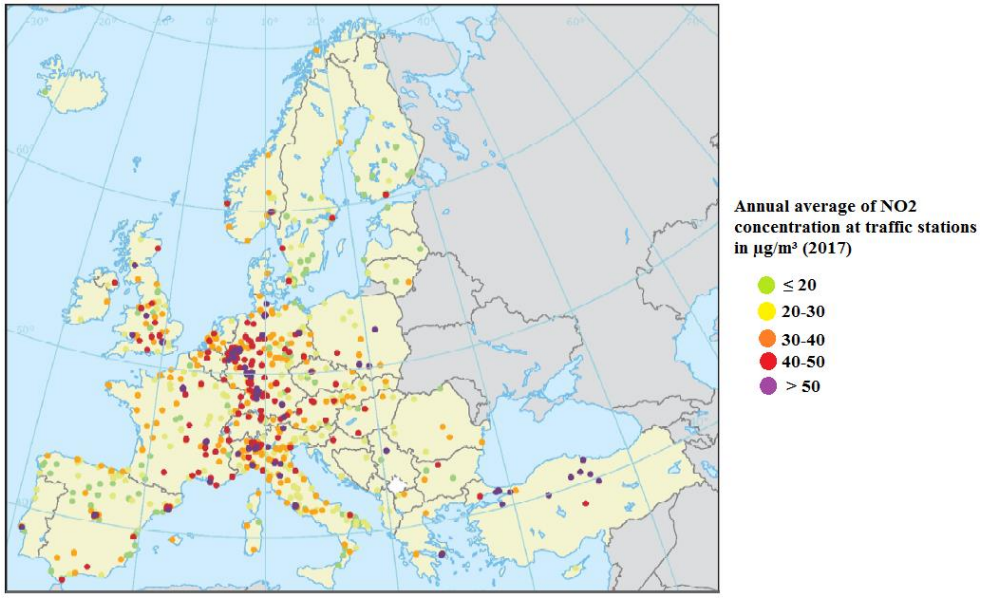

Fig. 1 Annual survey of the European Environment Agency regarding NO_2 limitations. Source: [4]

Electromobility is considered the suitable alternative to conventional mobility systems and has been gaining accent nationwide. In 2017 and 2018, the number of purely electric automobiles increased by 43%. Such increasing popularity has been caused due to the dropping battery prices, their longer ranges and broader choice of solutions. Such a development is anticipated to continue over the next multiple years with special subsidy packages, as addressed for example in literatures [5-8].

The compiled table 1, as follows, compares the energy intensity of production of electricity in the Central European countries. The next amounts of energy have to be consumed to use energy of 100 MJ (which is 28 kWh) in order for the final customer – the energy of primary sources from 44.4 kWh in Austria to 90.7 kWh in Hungary must be consumed to produce 28 kWh of electricity energy for the final customer [9].

Table 1 Comparison of energy intensity of electricity production in the Central European countries. Source: Authors, according to [9]

Output	Direct energy consumption (MJ)	Direct energy consumption (kWh)	Country	Overall energy consumption (W-t-W) (kWh)
Electric power	100	28	EU28	72.9
			CZ	85.7
			DE	80.9
			HU	90.7
			AT	44.4
			PL	87.5
			SI	60.4
			SK	75.0

2. Ongoing Projects Dealing with the Electromobility of Road Freight Transport

The first traction sections on the four-lane A5 motorway (always the right lane) in Germany between the cities of Langen and Weiterstadt have become part of the road transport infrastructure. Hybrid trucks with traction pans can charge batteries at full speed. Trial tests for a hybrid car powered from overhead lines were carried out for three months. According to the Hessen transport office [10], the first commercial hybrid vehicle is now in operation, another one is going to be in the autumn and the third one at the beginning of year 2020.

2.1 The Hessen "ELISA" Project

The Hessen "ELISA" project (Electrified, Innovative Heavy Freight Traffic on Motorways) is run by Hessen Mobil and funded by the Federal Ministry of the Environment (see the following Fig. 2) [11].

Fig. 2 ELISA - eHighway Hessen. Source: [11]

From the road operator's point of view, it is particularly interesting to obtain information on traffic engineering, road construction and operational aspects. The world's first eHighway was

launched in Sweden in June 2016 on the two-kilometer E16 north of Stockholm. Here, Siemens is involved in the research as well as in a similar project in California. Overhead line tests will be included in 2020 on the A1 motorway near Lübeck. A non-public test track already exists in Gross-Dölln in Brandenburg. By 2022, a total of five such vehicles from different forwarding companies, which will be supplied by Scania Commercial Vehicle Manufacturers from five, will participate in the trial operation. There are no valid data yet, but the hybrid vehicle showed no deviations in the laboratory investigations. The first interim evaluation is expected in the middle of 2020 [12].

The pilot project on the A5 motorway between Langen and Weiterstadt is going to test whether traction line technology is suitable for Germany, and whether it can be used for environmentally friendly and low noise emissions transport of goods on the road infrastructure. Effects on traffic, environmental and economic aspects, as well as extra work to maintain these roads, are going to be investigated. So far, the question of who is going to pay for the traction energy is unclear. Electricity is 100% supplied from renewable sources [11].

There will be more examination sections in Baden-Württemberg and Schleswig-Holstein. A total of 15 Hybrid vehicles will be produced by Scania's VW subsidiary for these tests. Driving technique is easy when the hybrid truck with traction pan is in the traction line section, powered by traction motors, and batteries can be recharged while driving. After leaving this section, the vehicle can then continue in the electric mode. If the batteries are discharged, the vehicle is powered by a diesel engine. The Elisa project - electrified, innovative heavy traffic on motorways - collects all the data that may be important for the further development of the system in Germany. Commercial vehicle manufacturers do not consider this system to be in competition with rail freight transport. The Federal Ministry of the Environment financed a 5 km route between Langen and Weiterstadt with EUR 14.6 million. The additional EUR 15 million will be spent on data collection and evaluation. If the system proves appropriate, not all motorways would have to be fully electrified. According to the ministry's estimates, about 1,000 km of motorways could be adapted for E operation in Germany, with an estimated cost of about EUR 1 million / km [11].

2.2 Deimler – Electric Truck Transport Project

Scania's competitor Daimler uses battery-powered vehicles instead of overhead line technology. The company is working on a technology that has a high probability of implementation worldwide. At the moment, the cost of overhead line infrastructure is very high, and given the rapid development of battery and fuel cell technology, Daimler is interested in comparing its electric trucks and the hybrid top-line vehicles on the planned track in Baden-Württemberg (see Fig. 3).

Fig. 3 Deimler – Electric truck transport project. Source: [13]

According to Daimler, there is already a similar system for the transport of goods with overhead lines, which works very well and it is called the German Railways. With the Electric Actros utility vehicle, the company has a flexible and already available concept - without costly, complex and lengthy planning measures. EActro prototypes are currently being tested and are expected to be manufactured from 2021 onwards. By Daimler, the network of e-truck charging stations is easier than the construction of traction lines. Equipping motorways with traction lines is extremely planning-intensive and expensive. It is also questionable who should operate the network [13].

One of the first test tracks for electric trucks with overhead contact lines is on the A1 motorway between Lübeck and Reinfeld in Schleswig-Holstein. The design work was provided by the Planning and Design Research and Development Center of the University of Applied Sciences of Kiel. The 5 km route is one of the three test tracks on which the Federal Ministry of Transport examines the use of overhead line systems for the electrification of heavy duty road vehicles. The pilot project is financed by about EUR 14 million. Experts from the National Mobility Platform (NPM) recommended the Federal Government to support the reduction of greenhouse gas emissions by switching to electric trucks on a similar principle as for electric trains that draw traction current using a pantograph. For trucks it would be the same system as for trolleybuses in passenger transport. The advantage over battery vehicles is that the batteries of these vehicles may no longer be as robust as they are used only for shorter distances [13].

With such vehicles, the Federal Government would save 52 to 55 million tonnes of greenhouse gases by 2030 according to the climate protection plan set. Unlike the Siemens concern, Daimler is not interested in participating in this project. The Electric Actros is in operation as a prototype and will be mass-produced from 2021 onwards. Daimler follows the same path as Volkswagen for passenger cars. Siemens emphasizes the undoubtedly higher running costs of electric vehicles with

respect to propulsion and overhead lines than with diesel or battery cars. For trolleybuses, operating costs are about 10 to 20% higher than vehicles with diesel engines. Because trucks are investment property, operating costs are critical to purchasing decisions. Electrically powered trucks and traction power take-offs are expected to cost up to EUR 20 000 per year on the assumption that the truck is 40 tons and its annual mileage is 100,000 km per year [13].

2.3 Other Projects

Experts expect investment costs for the construction of overhead lines of approximately EUR 3 to 4 million per kilometer, excluding the cost of new traffic lanes, but some studies are more favorable, expecting expenses of EUR 1.1 to 2.5 million. According to experts, if such a traction network is to have an impact on the climate, it must be up to 4,000 km by 2030. Battery vehicles have a range of up to 300 km. The Scandinavian countries were the first in the development of electromobility to conclude that by 2030 trucks would be independent of fossil fuels [14].

The world's first 2 km public motorway section was built on the E16 motorway north of Stockholm by Siemens and Scania (project called as the eHighway by Siemens). A similar test track in California is not open to public transport. However, there is considerable doubt that overhead lines are indeed the right technology to outweigh in the future. Other alternatives have been investigating for a long time. In the UK, for example, they are testing a motorway where power sources are stored under a road. This is an induction technology designed to supply trucks and cars with power while driving [15].

Also in Germany, the Fraunhofer Institute for Production Technology and Applied Materials Research tested this principle on a former test track for the Transrapid system. The conclusion is that this technology is not yet advanced, yet it works for slow cars on the road. In trial operation the speed was up to 30 $km.h^{-1}$. Speed is a challenge because the magnetic coils used to transmit current in induction technology must be turned on and off at the right time. According to scientists, this technology could work, but up to 200 $km.h^{-1}$. Traction lines in Sweden are designed for speeds of up to 90 $km.h^{-1}$, but are not suitable for passenger cars [16].

Daimler will produce mass-produced eActros from 2021 onwards. It wants its vehicles to be emitted without emissions and in a noiseless mode in cities. Vehicle testing is carried out in Stuttgart and Switzerland with regard to the daily usability and economy of operation. Trucks have a weight of 18 or 25 tons with a range of up to 200 kilometers. They are intended for local distribution, for example to supply supermarkets. The technical starting point for eActros is the heavy three-axle distribution vehicle. The conventional powertrain is replaced by an electrically driven rear axle with electric motors located directly next to the wheel hubs. The new axle was derived from the construction of the Mercedes-Benz Citaro Hybrid bridge bus [17]. Power is

provided by a battery consisting of three lithium-ion battery modules with a range of up to 200 km in distribution operation. The integrated drive axle concept near the frame-mounted battery is impact resistant. Cities such as London and Paris are considering banning internal combustion engines in their centers with respect to e-cars being tested by Daimler or Volvo. The European Commission supports the increase in the permissible total weight of alternative-drive trucks by up to one tonne, the additional mass of electric propulsion 1.7 tonnes being largely balanced by the total permissible weight of eActros, which increases from 25 to 26 tonnes. The payload is therefore only 700 kg lower than a directly comparable truck with an internal combustion engine [13].

3. Main Findings and Discussion

Improving air quality, lowering noise levels and reducing the entry of internal combustion engine trucks have become important slogans in major cities around the world. More and more people are moving to cities around the world. Since 2008, more people have been living in cities than in rural areas, and this trend continues. The UN estimates that by 2050 the Earth's population will be 9 billion, with about 70% living in cities. In the future, it will be important to transport goods to more and more people in urban areas - with the least possible and most quiet emissions [18, 19].

Electromobility technologies are much more advanced, especially batteries are developing rapidly. For example, Daimler Trucks expects the cost of batteries for a fully electric truck to drop by a factor of 2.5 from 1997 to 2025 - from EUR 500 / kWh to EUR 200 / kWh. At the same time, power increases from 80 Wh / kg to 200 Wh / kg during this period [9].

Daimler Commercial Vehicle Subsidiary Mitsubishi Fuso Truck and Bus Corporation wants to electrify all its vehicles, as announced at the Tokyo Motor Show 2017. The vehicles will be sold under the new e-Fuso brand. The 23 t electric truck with a range of up to 350 kilometres has a payload of 11.11 t, which is only 1.8 t less than its diesel version. The distinctive futuristic design, spacious and minimalist interior, modern connectivity and communication features make e-Fuso Vision One a bold look at the company's future products. In 2020, Daimler will participate in a pilot project with traction line for trucks on a test track in Baden-Württemberg. According to a statement by the Ministry of Transport in Baden-Württemberg, it is to carry out logistical tasks in parallel with the hybrid trolleybuses already in operation. By the end of this year, a 6 km section on the B 462 road in Murgtal between Gernsbach-Obertsrot and Kuppenheim with overhead contact lines in both directions will be ready for the project. Trucks will draw power from overhead lines while charging batteries [20, 21].

Forwarding companies Fahrner Logistics and Huettemann Logistics want to use hybrid trucks from 2020 onwards. Each year, three paper manufacturers in Obertsrot transport more than 500,000 tons of paper and cardboard to the logistics centre in Kuppenheim. The trial operation is planned for

3 years. The Federal Ministry of the Environment finances this project with an amount of EUR 16.8 million. New York Siemens tested the first “electro-motorway” with overhead contact line in the US in 2015. Both electric and diesel trucks get the electricity they need, such as overhead line trolley. In Los Angeles, this road for electric cars was built as the first in the world. The examined section has a length of 3 km and is built on the Interstate 710 motorway. In the near future, the electric truck motorway will connect the two largest US ports in Los Angeles and Long Beach, 30 km away, with up to 35,000 trucks in 24 hours [22-24].

4. Conclusion

As aforementioned, the system of electric vehicles for road freight transport is based on the experience with the operation of trolleybuses, which have the same power supply of traction motors from the overhead traction line by means of traction pantographs. Discussions are underway as to whether this system is unnecessarily expensive, as traction power lines must be built along roads, which also has an impact on landscaping. Another solution consists in a power supply from induction cable, similarly to the system of autonomous guided vehicles in combined transport terminals or waterway ports (AGV Automated Guided Vehicles); however, there is a problem with low speeds up to 30 $km.h^{-1}$ or with battery power.

In view of the above investigation, the implementation of transport policy preferring the electromobility development does not necessarily have the analogous ecological effect in each EU country. As confirmed, electromobiles charged by a grid, for example in Poland, are not as environmental friendly as e-mobiles charged in Austrian regions. Hence, as far as the future research is concerned, it is necessary so that individual countries, involved entities and parties deal not only with putting the very electromobility into operation; nevertheless, they must also refine and upgrade environmental aspects of production of electric power, as well as improve an effectiveness of the electric power transfer.

References

[1] Sarkan, B., Caban, J., Marczuk, A., Vrabel, J. & Gnap, J. (2017). Composition of exhaust gases of spark ignition engines under conditions of periodic inspection of vehicles in Slovakia. Przemysl Chemiczny. 96(3), 675-680. DOI: 10.15199/62.2017.3.36.

[2] European Commission. (2008). Climate Action – 2020 climate & energy package. Retrieved October 20, 2019, from https://ec.europa.eu/clima/policies/strategies/2020_en.

[3] Appunn, K. & Wettengel, J. (2019). Germany’s greenhouse gas emissions and climate targets. Journalism for the energy transition. Retrieved September 29, 2019, from

https://www.cleanenergywire.org/factsheets/germanys-greenhouse-gas-emissions-and-climate-targets.

[4] European Environment Agency. (2018). Air Quality Standards – Nitrogen dioxide. Retrieved October 05, 2019, from https://www.eea.europa.eu/themes/air/air-quality-standards.

[5] Pawełczyk, M. & Szumska, E. (2017). Evaluation of the efficiency of hybrid drive applications in urban transport system on the example of a medium size city. In MATEC Web of Conferences. 180, 5-7 October 2017 (Article no. 03004). Warsaw, Poland. DOI: 10.1051/matecconf/201818003004.

[6] Carbon, C.C. & Gebauer, F. (2017). The Safe-Range-Inventory (SRI): An assistance tool for optimizing the charging infrastructure for electric vehicles. Transportation Research Part F: Traffic Psychology and Behaviour. 47, 101-113. DOI: 10.1016/j.trf.2017.04.011.

[7] Michalski, J., Poltrum, M. & Bünger, U. (2019). The role of renewable fuel supply in the transport sector in a future decarbonized energy system. International Journal of Hydrogen Energy. 44(25), 12554-12565. DOI: 10.1016/j.ijhydene.2018.10.110.

[8] Fernández, R.Á. (2019). Method for assessing the environmental benefit of road transport electrification and its influence on greenhouse gas inventories. Journal of Cleaner Production. 218, 476-485. DOI: 10.1016/j.jclepro.2019.01.269.

[9] Skrúcaný, T., Kendra, M., Stopka, O., Milojević, S., Figlus, T. & Csiszár, C. (2019). Impact of the electric mobility implementation on the greenhouse gases production in Central European Countries. Sustainability. 11(18). DOI: 10.3390/su11184948.

[10] EUROTRANSPORT.DE. (2019). E-mobilitaet vollelektrisch auf der nufam. Retrieved September 11, 2019, from https://www.eurotransport.de/.

[11] ELISA - eHighway Hessen. (2018). ELISA - Elektrifizierter, innovativer Schwerverkehr auf Autobahnen. Retrieved October 10, 2019, from https://ehighway.hessen.de/ELISA.

[12] Harttmann, C. (2019). USA: Daimler liefert die ersten elektrische Freightliner eCascadia aus. Transport – Die Zeitung für den Güterverkehr. August 22, 2019. Retrieved September 07, 2019, from https://transport-online.de/news/usa-daimler-liefert-die-ersten-elektrische-freightliner-ecascadia-aus-17746.html?xing_share=news.

[13] Von Wilkens, A. (2018). Elektro-Lkw eActros: Daimler will Elektro-Lastwagen ab 2021 in Serie bauen. Heise Online. February 21, 2018. Retrieved October 21, 2019, from https://www.heise.de/newsticker/meldung/Elektro-Lkw-eActros-Daimler-will-Elektro-Lastwagen-ab-2021-in-Serie-bauen-3975056.html.

[14] Von Wilkens, A. (2019). Elektro-Lastverkehr: Daimler stellt sich gegen Oberleitungen. Heise Online. April 16, 2019. Retrieved October 17, 2019, from https://www.heise.de/newsticker/meldung/Elektro-Lastverkehr-Daimler-stellt-sich-gegen-Oberleitungen-4400894.html.

[15] Siemens Mobility GmbH. (2017). Electrified road freight traffic – the eHighway by Siemens. November 08, 2017. Retrieved October 18, 2019, from https://press.siemens.com/global/en/feature/ehighway-solutions-electrified-road-freight-transport.

[16] The Fraunhofer Institute for Production Technology and Applied Materials Research. Transrapid system, Adhesive bonding technology, Adhesive bonding in transportation construction.

[17] Buchner, S. (2019). Mercedes-Benz delivers electric eActros heavy-duty truck to Logistik Schmitt for testing; countering catenaries. In: Green Car Congress: Energy, technologies, issues and policies for sustainable mobility. February 15, 2019. Retrieved October 18, 2019, from https://www.greencarcongress.com/2019/02/20190215-eactros.html.

[18] Vidová, J. (2018). Environmental policy and electromobility in European Union. Waste Forum. 4, 503-513.

[19] Birkner, M. (2012). Electromobility for heavy-duty vehicles (HDV). In 26th Electric Vehicle Symposium 2012 - EVS 2012. 3, 6-9 May 2012 (1747-1752). Los Angeles, United States.

[20] Golovanov, N. & Marinescu, A. (2019). Electromobility and climate change. In 8th International Conference on Modern Power Systems - MPS 2019. 21-23 May 2019 (Code 149545). Napoca, Romania. DOI: 10.1109/MPS.2019.8759786.

[21] Lewicki, W. (2017). The case study of the impact of the costs of operational repairs of cars on the development of electromobility in Poland. The Archives of Automotive Engineering. 78(4). DOI: 10.14669/AM.VOL78.ART8.

[22] Chargui, T., Bekrar, A., Reghioui, M. & Trentesaux, D. (2019). Multi-objective sustainable truck scheduling in a rail-road physical internet cross-docking hub considering energy consumption. Sustainability. 11(11). DOI: 10.3390/su11113127.

[23] Rymarz J., Niewczas A. & Stokłosa J. (2015). Reliability Evaluation of the City Transport Buses Under Actual Conditions. Transport & Telecommunication. 16(4), 259-266.

[24] Kravtsiv, V., Kolodiichuk, V. & Kolodiichuk, I. (2018). The greening of transport and logistics systems of regional agricultural markets. Economic Annals-XXI. 171(5-6), 38-43. DOI: 10.21003/ea.V171-06.