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Electromobility: Will a changeover to electric-powered vehi-cles make transport systems environmentally friendly?

Working Group of German and Austrian Emeritus Transport Professors

Foreword

A group of emeritus professors in transport studies and retired directors of transport re-search institutes at German and Austrian universities meet annually in Fulda, Germany, to discuss evolving issues in the transport field. At these gatherings, much attention has been paid to developments surrounding the use of electric-powered vehicles in urban and re-gional transport systems. At their most recent meeting, the transport experts have called on all involved parties to use the emerging technical possibilities responsibly for the general welfare of persons, cities and the environment, and to make a realistic assessment of what these possibilities in fact are and what their effects will be (see accompanying text).

The transport experts see long-term opportunities to improve climate and environmental protection in urban and regional transport systems through the use of electromobility. How-ever, they point out the necessity of introducing these new technical possibilities with an informed overview of the overall context of urban and regional transport systems and settlement patterns. They identify the many as yet unclarified technical questions associated with electromobility. In this connection they call for an augmentation of the strategic ap-proach "Clean Energy in Transport" outlined by the Austrian Transport Ministry (bmvit). For an independent performance review of electromobility developments, a "national electromo-bility expert platform" should also be established in Austria as well as in Germany, which includes independent experts from the field of transport planning. The professors call for a comprehensive impact assessment and also for an informed consideration of possible nega-tive effects that may occur in the development of electromobility.

Increased use of electrically powered road vehicles in personal and freight transport in the pursuit of climate protection goals and new technological developments is foreseeable. To ensure a positive impact on solving future transport and environmental challenges in urban and regional areas it will be necessary for the involved political decision makers to establish the necessary framework and parameters without delay.

There are, however, many open questions that must be clarified in order to take these im-portant steps. More intensive participation of the involved cities and regions, civil society, political actors and policymakers, administrative bodies and business leaders in this crucial process is therefore essential.

Electromobility: Will a changeover to electric-powered vehicles make transport systems environmentally friendly?

1. All forms of energy generation and use entail costs

In the current public discussion, the technology of the drive systems used for cars and trucks has been brought into close connection with desired changes in the global climate and environment. Limiting global warming is recognised as an important objective around the world. An effort to limit CO_2 emissions in accordance with the Paris Agree-ment is one focus of this effort. Another focal point concerns nitrogen oxide emissions coming from diesel-powered vehicles, an additional matter which demands effective countermeasures. Both of these goals give rise to demands for change in the transport and mobility concepts used in the field of vehicle propulsion systems – particularly in urban areas.

Road-based transport is responsible for a significant portion of ongoing CO_2 emissions. In the past, the principal effort to reduce CO_2 emissions has been made through the de-velopment of more efficient internal combustion motors. Another possible route to re-duce such emissions could be the use of electrically powered vehicles in connection with modern battery technology and fuel cells or hydrogen combustion. More and more gov-ernmental support is available for such developments, which also have a growing posi-tive reception in the general public discourse. In consequence, they are being pursued more and more intensively by the involved industries. Nonetheless, it is necessary to pose the question to what degree e-mobility really serves environmentally friendly trans-port policy and what secondary effects are associated with it.

Against the background of ongoing discussions of exhaust emission values from diesel motors that have become almost incomprehensible, the public debate regarding future transport systems is concentrated mainly on various vehicle propulsion technologies, which should either be required or regulated one way or another. This is particularly the case for electric-powered vehicles. A possible mandatory introduction of such vehicles by a certain date (e.g. 2030) has been the subject of heated debate among politicians of various parties in Germany and Austria. In this situation, it is useful and necessary to undertake a comprehensive scientific assessment of the current efforts to develop more efficient and environmentally sound drive systems for vehicles. This should also include an identification of the deficiencies of the existing debate as one important step in find-ing the most promising way forward.

There exist only highly specific and not easily comparable[1] compilations of the advan-tage and disadvantages of various vehicle propulsion energy sources due to the com-plex chains of factors in the production and use of energy. Depending on the standpoint taken in the debate regarding future energy sources, only certain advantages of the one or the other type of energy are highlighted, depending on the interests of the involved parties. Often one gets the impression in this type of discussion that the laws of physics (which of course underlie the entire situation) are simply being ignored. It is a fact that in the production, storage and use of energy, energy consumption is necessary, which typically involves direct or indirect emission of pollutants and the use of limited re-sources.

1 Also of significance in the production chain of energy (including the storage of the produced energy) are perti-nent social factors such as child labour, oil production in nature sanctuaries, etc. Although relevant, these factors will not be considered in mor detail here.

Of course, it is advantageous if at least part of the energy used to power vehicles comes from renewable sources (wind, solar). In the current discussion, however, often the prob-lems of alternative power sources (electric vehicles) are not adequately considered. In the following paper, the main alternative to the internal combustion motor currently under consideration – namely, battery-powered electric vehicles – will be analysed with regard to a number of disadvantages that to date have received little attention. Other electric-powered alternatives such as fuel-cell vehicles will not be considered here even though many of the factors that will be cited also are relevant for such systems. In the following examination, existing deficits in the current strategy will be identified which urgently need to be addressed.

2. Deficits in the comparison of electric-powered vehicles and other forms of pro-pulsion

2.1 Disregard of the size and weight of vehicles

It is well known that all forms of technical progress can also trigger so-called "rebound effects" (see Santarius, Tilman, 2012). Thus, for example, the energy savings that are achieved by more efficient vehicle drive systems are at least partially dissipated through more intensive vehicle use as well as the purchase and use of larger and heavier vehi-cles with greater engine power while operating costs are kept more or less constant. Precisely this rebound effect was in evidence in recent years with the ever more exces-sive engine capacity in passenger cars – with increasing vehicle size and performance. In connection with the introduction of electric vehicles, however, this type of development has not yet received the attention that it should.

It is already foreseeable, however, that the automobile manufacturers are aiming to fol-low the example of the Tesla Model S and will bring large and heavy electric vehicles to the market while categorising such vehicles as "ecological". The involved energy losses occurring through sheer size[2] and weight have not been addressed

2 Energy consumption increases disproportionately to the size of a vehicle's frontal surface.

– either as a technical or a political topic[3]. This strategy is abetted by current law that on the one hand re-quires that specified fleet averages in fuel consumption or CO_2 emissions are met while calculating the emissions from electric-powered vehicles as zero and falsely undercalcu-lating the values for hybrid-drive vehicles. Even without the electrification of vehicles and most certainly with it, there is an urgent need to limit the size and weight of passenger cars or at least to subject it to taxation.

2.2 Disregard of acceleration

Owing to the characteristic line of their motors, electric vehicles can accelerate very rapidly at all speeds. In all the relevant publications, this is judged nearly without excep-tion to be a great benefit (a "delightful driving experience", etc.). That the acceleration realised with these vehicles also consumes energy is only mentioned peripherally, if at all. That the increased acceleration in urban settings may be exceedingly dangerous because the vehicles approach at once swiftly and silently, thus denying pedestrians and bicyclists the necessary time to react and avoid accidents, is also hardly mentioned. Nor is it considered that the increased acceleration results in higher rates of wear to the roadway and to tyres with increased levels of particulate emissions. A limitation of ac-celeration capacity in electric vehicles (which presents no technical problems) is there-fore urgently required[4], also for safety reasons as the reflexes of drivers in an aging society are also declining.

2.3 Use of the description "emission-free" or "locally emission-free" for electric automobiles

It has often been stressed that electric vehicles generate no emissions – and thus are emission-free – in the locations where they are used (in urban centres, for example). However, in accordance with the laws of physics, emission-free movement of a larger mass is simply not possible. The fact that the electricity is produced at another removed location and that it may well be that "indirect emissions" are produced there is only ac-knowledged with the formulation "vehicles that are locally free of emissions"[5].

However, even this description is not correct. The fact is that the particularly dangerous emissions, namely fine particulate matter, are also generated with the operation of elec-tric vehicles. The street cross section at the Neckartor location in Stuttgart has been very thoroughly studied in connection with the current debate regarding diesel motors in Germany. The particulate matter there has been analysed in detail to determine its ori-gin, and it has been shown that at least 85% of emitted particulate matter in the size of PM 10 does not come from the motors of the involved vehicles. This is a very complex situation[6]. Measurement results obtained by the State Institute for the Environment and Conservation in Baden Württemberg (LUBW) are regularly updated on the website of the Institute. A useful summary of the findings is provided in an article by Christof Vieweg[7].

2.4 Disregard of energy consumption of electric vehicles or of the distances covered with electric power by plug-in hybrid vehicles

Axel Friedrich, the former head of the UBA researching for the German environmental organisation "Deutsche Umwelthilfe", has rightly demanded that *"efficiency standards must also be established for electric automobiles to prevent the waste of valuable ecologically generated electricity[8]."*

Ecologically generated electricity is not available in unlimited amounts at a given time or place. At night when the wind blows less strongly, every kilowatt hour is particularly valuable (more on this later).

3 In addition, effects such as road wear should be considered. Calculated approximately (Cambridge Road For-mula), road wear increases at a power of 4 relative to axle load; a vehicle with twice a given weight increases road wear by a factor of 16.

4 Outside of urban areas, the reflex of increasingly elderly drivers will in many cases also not be commensurate with the possible rates of acceleration.

5 A comparison of the emissions caused through the production of electricity with those resulting from motor com-bustion will not be undertaken here. The literature on this subject is as diverse as the various viewpoints regard-ing this topic.

6 Depending on the particle size, differences can occur which bring turbocharged petrol-fuel motors into focus as a causal agent.

7 Vieweg, Christof: Feinstaub – Die Motoren sind nicht das Problem, in ZEIT-online (2017).

8 See, Friedrich, Axel (2017).

To act as if the energy consumption levels in electric vehi-cles are irrelevant – as suggested by terms such as "zero emissions" or "zero energy" – has serious consequences. Because these figures have also been used for the official consumption levels, it benefits the manufacturers to replace large and heavy combustion vehicles with high CO_2 emissions through large and heavy (or even heavier) electric vehicles so that the "fleet consumption value" is effectively reduced for the brand as a whole.

This has a particularly unfortunate effect with the regulation for plug-in hybrid vehicles which in practical use only achieve low consumption values of combustion fuels when there is a sufficient amount of electric recharging. Even the specified petrol/diesel con-sumption values used for the fleet consumption figures are highly unrealistic due to the overestimation of distances covered with electrical power, which are included in the cal-culation with a "zero" value. In all of this, the question of the production, storage and dis-tribution of electricity remains unclarified as well as the specific degrees of energy loss occurring in the course of these processes. The availability of sufficient capacities in the power grid to accommodate charging infrastructure is also not automatically available.

It is essential that a standardised value for total CO_2 emissions has to be introduced. An efficiency standard for electric vehicles could be the CO_2 equivalent value[9] of consumed electrical energy in an RDE (real driving emission) test. It would also be an ad-equate orientation value for plug-in hybrid vehicles because it would generally reflect the disadvantageous additional petrol consumption resulting from the overall higher weight of such vehicles. The CO_2 values set in EU regulations must reflect these real condi-tions. They then will be more realistic and not set at an illusionary low range.

9 In accordance with the current energy mix so that in general an impetus is created for the development of eco-logical energy production.

3. Errors and misconceptions regarding energy provision

3.1 Providing energy for electric vehicles is no problem

It has already been mentioned above that ecologically generated electricity is particularly valuable. Making such power available in the desired quantities without time-based or location-based limits will not be possible in the directly foreseeable future. In addition, there will be other consumers of such energy, for example in the heating sector if the goal of completely eliminating CO2 emissions for such purposes is to be met. The en-ergy requirements for heating will compete particularly with the requirements for char-ging electric vehicles, especially on winter nights (despite reduced night-time heating needs). The scenario of a windless winter night in the year 2050 indicates that consider-able investments in power storage facilities will be necessary if ecologically generated electricity is going to be continuously available – and that is the case even without con-sidering requirements for electric motor vehicles. Besides the storage facilities, a com-prehensive expansion of the power grid will be necessary to accommodate the production possibilities of green power at locations removed from the place of use. Many loca-tions are currently only equipped with power supply connections of insufficient capacity. Currently we do not have integrated concepts for ecological electricity generation, its large-scale and decentralised distribution, its storage and the storage-orientated conver-sion (to-liquid / to-gas …).

The generation of the total power necessary for electric vehicles is in itself a significant challenge[10], if one supposes that all of the currently used fossil-based fuel is to be re-placed by electric power. Nonetheless, with the appropriate level of effort – which how-ever must commence immediately – this should be possible, particularly because the scenario "Everyone has an electric car" will not in fact be realised so quickly.

10 See the exposition of the physicist Vince Ebert (2017) in "Spektrum der Wissenschaft" which makes reference to the peak loads that can be expected. This presentation may be questionable regarding certain details but in its general thrust it is entirely correct.

3.2 Disregard of local and time-based peak requirements for energy with e-mobility

The current discussion regarding e-mobility and electric vehicles has mostly been con-ducted by economists and automobile technicians with little participation from transport engineers. For many years, these specialists have directed their attention to the connec-tions between settlement patterns and transport needs arising in response to daily, weekly and annual occurrences and the particular problems of handling spatial and temporal peak loads. If these peak loads did not occur, we would require far fewer roadways and transport area in total. Managing the spatial and temporal peak loads in transport demand represents a special problem – quite without the planned decommis-sioning of all coal, gas and nuclear power plants. Feasible concepts to handle these challenges with comprehensive operation and development strategies are lacking at the current time.

The efforts to level out peak hours of transport use run up against very strict limits – as can be seen in everyday life. Measures such as time-of-day-based fees for the use of streets or charging of electric power inevitably have social consequences. More wealthy persons can drive or charge whenever they want, while less prosperous households do not have such options. Equal access to such infrastructure, however, is part of the public services that we aim to provide and a key element of social inclusion. Price-based measures are therefore only acceptable with careful consideration and balancing of their social impact.

Extreme peaks (both time and location-based) occur in transport volume – not only seasonally on certain days with holiday and leisure travel at certain weekends, but also at certain hours with daily commuting. This will not be simple to handle with the demand for electric energy to power electric vehicles in future. Ideas are in development that would tend particularly to reduce nightly charging (e.g. "charge at work") and also would make use of well-supplied locations. However, substantial costs are to be expected for such measures and the required infrastructure development.

Because charging current does not simply flow out of the socket, all measures that im-pact transport behaviour and make it so that automobiles are used less intensively than presently will become even more important through the process of electrification of ve-hicular transport. The ongoing development in demand for motorised means of trans-port, which has not in the least reached its peak in Europe or internationally, can also not be ignored.

3.3 Electric cars do not require additional power storage in the grid because they themselves serve as power storage units and can be used as such

The argument is often made that the batteries of electric vehicles can themselves be used as a power storage facility as part of an intelligently managed "smart grid". For this reason, large vehicles with large batteries will be one aspect of the solution rather than a problem. In making this argument, it is overlooked that the daily time-based need for power with electric vehicles will probably not allow this. In the morning, the electric car should be fully charged, therefore it cannot provide power at night for light and - particu-larly in winter - for heating and warm water. If the full battery capacity is not available in the morning, then it may be that the whole daily programme cannot be implemented.

Today, the peaks of electricity generation in certain areas, such as the surpluses of wind-generated power in Northern Germany, cannot be effectively transmitted through the grid to other areas such as Southern Germany. All the computers in a smart grid still cannot send the power of a full battery in a vehicle in Kiel to a household in Munich if the capacity constraints of the grid do not allow this. Therefore a comprehensive optimiza-tion concept taking time and distance factors into account to effectively handle the distri-bution of power generation, energy transport via networks and energy storage so as to cover energy demand for transport, heating, industry, etc. needs to be prepared, fi-nanced and ultimately implemented.

4. Consequences

Every form of vehicle propulsion creates problems, and this is no less true for electric power. Concerted efforts must be undertaken as soon as possible within each state, on an European level and internationally if electric power is to provide competitive as well as ecologically sound and socially acceptable mobility and the future of electric propul-sion is to be ensured. For electric power, these problems on the one hand are caused in particular by the demands regarding weight, speed and acceleration in a new generation of vehicles. On the other hand they derive from the actual energy consumption and transport behaviour that may occur with such vehicles.

The expenditures necessary for the creation and maintenance of new infrastructure as well as the energy consumption in the production and disposal of vehicles and batteries represent further areas of concern.

A future without CO_2 emissions from motor vehicle use definitely cannot be achieved if we hold to the current level of motorisation and mileage found in developed western countries today, possibly with vehicles that are even heavier and have higher levels of acceleration that those in use today. If we transfer only 50 percent of the current level of motorisation found in Germany or similar western countries to the world as a whole, then the number of vehicles on the planet would increase from the recently reached figure of one billion to two billion. With the transfer of the full level of motorisation to the rest of the world, there would be four billion automobile, a quantity that torpedoes any notion of en-vironmental compatibility.

The goal of switching over to propulsion systems for motor vehicle transport without CO_2 emissions is necessary for the mid-term and long-term protection of the global climate and environment. In pursuing this switchover, the current misconceptions regarding electric propulsion need to be avoided. Without infrastructure planning for settlement and transport that reduces the overall transport activity, any conceivable form of automo-tive transport – including electric propulsion[11] – will result in a global burden that is un-sustainable and intolerable. A public debate that includes issues of alternative settle-ment and transport infrastructure planning, in particular with improved concepts for non-motorised transport and public transport as well as the problem of truly representing the overall economic costs of different transport options is essential for a comprehensive view of the challenge facing us, as is a debate regarding the propulsion systems for vehicles. But these infrastructure issues are not popular and thus amount to a sort of taboo subject in transport policy.

Viewed as a whole, it is urgently necessary to include the development of new propulsion technologies in an integrated approach to transport policy. This must not simply rest on questions of technical innovation but also include policies for managing changes in demand and behaviour in order to achieve defined goals (e.g. in CO_2 und NOx reduc-tion). In these efforts, the measures to reduce overall transport volume (sufficiency) must complement the strategies to improve efficiency and modal shifts (consistency). The electrification of bicycles, delivery vehicles/lorries as well as public transport that is cur-rently powered with fossil fuels also needs to be integrated into a comprehensive ap-proach.

11 Several publications which make the elimination of combustion motors the central issue of discussion are there-fore highly questionable. A close reading, for example of the study of the Wuppertal Institute for Greenpeace (Rudolph. F. et al, 2017) which calls for the elimination of combustion motors reveals that the prerequisite for this elimination for 2035 includes a level of motorisation at half the current level, lighter automobiles, a huge ex-pansion of public transport and a general shortening of distances travelled in everyday life. But these are pre-cisely the challenging points which are not sufficiently addressed in the study.

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