The Vision of E-Mobility in the Perspective of the Existing Power Infrastructure

Successfully managing conflicting expectations

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***Abstract*—Replacement of vehicles with internal combustion engines by electric vehicles (EV) is considered being an important change in terms of sustainability and climate protection. This change is complex and affects much more areas of society than just transportation. Also power system planning and operation require attention when creating the preconditions for the transformation. Medium- and long-term policies need to be designed consistently in order to achieve the objectives.**

Keywords-electric vehicle; charging; power system; climate policy

I. THE RATIONAL OF E-MOBILITY FROM A POLICY MAKER'S PERSPECTIVE

Converting transportation from internal combustion engines (ICE) to electric vehicles (EV) is seen as one of the major challenges for infrastructure and environmental policies for the next decade. At European level, a basic legal framework has been put in place [1]. Worldwide, since 2012 impressive growth rates of about 50% per year have been recorded. With total sales of about 760.000 vehicles worldwide, the market is still in an early stage [7].

One important driver for E-mobility are climate policies: decarbonisation of transport is key for the reduction of overall CO2 emissions. In Germany, road transport currently accounts for annual CO2 emissions of 153 Mt out of a total of 776 Mt, i.e. about 17% of the national total [2]. Nevertheless, climate is not the only argument for E-mobility. In particular, in metropolitan areas the reduction of the environmental impact on a micro scale is at least as important. E-mobility promises to reduce or eliminate local problems like smog created by the emissions of volatile organic compounds (VOCs), dust and noise. By reducing the dependency on oil, for many countries E-mobility also has the potential to reduce the dependency on energy imports.

For judging the effectiveness of E-mobility as a component in society's decarbonisation efforts, of course, the fuel mix in electricity generation is decisive. The replacement of gasoline by electricity adds some substantial portion to system load. The new load pattern will differ from the current profiles. As a consequence, specific emissions with enhanced shares of E-mobility cannot simply be extrapolated based on current fuel mix and merit order of the existing power plant population. For that reason, E-mobility does not automatically mean reduction of CO2 emission. Careful policy design is required in order to make sure that the desired effect is achieved.

II. SEGMENTS IN TRANSPORTATION AND POLICY AREAS

In the discussion on mobility this keyword often is used synonymously with individual road traffic in privately owned vehicles. Assessing the requirements of E-mobility, such an implicit definition is easily misleading. The specific requirements and preconditions in other segments of mobility simply are too different.

Figure 1. just indicates the many segments which can be distinguished in transportation. When evaluating technology capabilities, institutional framework, regulation etc., each of the segments down to the lowest level has its own specifics. Looking from this perspective it is obvious that there is not one single technology and / or one single policy when talking about the transformation towards E-mobility. Additionally, the categories in the graph are overlapping and the same categories appear in deeper levels. For example, public and individual transport exist in rural as well as in urban areas. Still the requirements in these sub-segments are different.

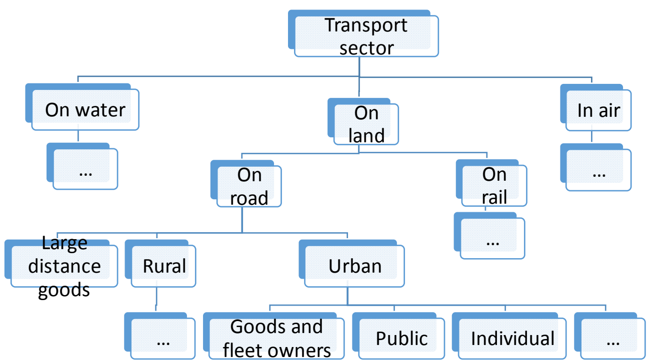

Figure 1. Indicative illustration of segments in the transport sector

One major policy objective might be shifting road based to rail based transportation because this allows immediate electrification. Another policy might try to stimulate electro-traction with fleet owners in urban areas because some preconditions and access to the target groups are easier than in the case of individual transport.

Even within the lowest subcategory, requirements are diverse. A vehicle used for daily home-work traffic in urban areas makes many short trips. Once a year, however, it may also be used for family vacations. This combination of functions results in completely different specifications than separating them. Long distance range and technology compatibility over extended geographical regions are only important incidentally. When designing policies for the large scale changeover to E-mobility it is not only important to define the segment. It is also decisive to separate mobility functions and to potentially rearrange them differently than in the past. Otherwise, many promising solutions will be discarded even before considering them. This broader perspective is emphasized by prominent stakeholders (e.g. [8]

In the following discussion we focus on one important part of traffic in urban areas: the daily trips of individuals with privately owned vehicles.

III. EV REQUIREMENTS AND IMPLICATIONS FOR INFRASTRUCTURE

An analysis of mobility patterns is the starting point for an assessment of the demands created by EVs in urban areas for transportation of individuals. Various empiric investigations exist [3], [4], [5], [6], [7]. For Germany, they show an average of about 3 trips a day consistently for the total population as well as for urban areas in particular. Distances per trip vary by purpose in a range between 5 and 20 km with an average around 10km. Only 20% of all trips with cars cover a distance longer than 20 km [5].

This usage pattern is a strong argument for mobility offers with limited range capability. Nowadays, storage capacity is a major cost driver, covers a significant share of vehicle weight and is one of the components with the shortest service life. Reducing the need for storage is the easiest way enabling E-mobility. Obviously, this rational is in contrast with major development efforts of the automotive industry. The template there is the existing vehicle with ICE designed to run hundreds of km – twice a year.

Regardless, the EV design, the usage patterns determine requirements for typical charging times and intensity. Vehicle usage is stochastic in terms of time and space and so are the charging demands. E-mobility in urban areas calls for a dispersed charging infrastructure.

The required charging capacity depends more on usage than on the installed capacity in the vehicle. The energy to be recharged in first order is a function of the energy drawn from the battery before for driving. To a certain extent, design of the charging infrastructure has no relation with design trends of the vehicles. Again, it is a choice to choose or not to choose the exceptional situations with a completely discharged wide range battery as the basis for the specification of charging points.

Due to mobility patterns there will be peak periods for charging demand creating respective load profiles. In liberalized electricity markets these profiles have to be served by traders. The specific challenge of E-mobility is the independence of contractual relationship and infrastructure and location. Addressing this issue adequately in regulation was one of the preconditions for any acceptable charging infrastructure.

There are more factors having implications for infrastructure requirements. It would be naïve to ignore habits and user expectations which have been grown over decades. Tolerance for loss of convenience at the end users side will be quite limited. Insufficient density or inappropriate location of parking slots with charging points will have an immediate adverse impact on adoption of this new technology. This is also important as there will be a significant period where ICE and EV will coexist and end users have their choice. The length of this period, in turn, strongly depends on the willingness and motivation of end users and consumers to make a change.

IV. IMPACT ON POWER NETWORKS AND LIMITATIONS FOR EV ROLLOUT

Earlier scenario studies concluded that the impact of E-mobility on power system and distribution network planning & operation is limited [9]. The results suggested that – with a few exceptions – existing infrastructure is sufficient to support integration of large numbers of EVs in the German power system. The conclusions however may need review. Key assumptions of the study are outdated, the most prominent example being the assumed capacity of the charger. In that time 3.7 kW was used as modelling assumption. Currently, even for normal charging 11 kW is the reference [10] and implementation of thousands of high power recharging points with at least 22 kW has been announced.

This difference is significant. Distribution system operators may be unable to provide the expected service with the existing assets. Extension of the network is faced to serious restrictions. Space in urban areas is limited and construction works are complex. Planning is time consuming. Additionally, it is still undecided how the costs of network extensions for E-mobility should be covered. Is this infrastructure part of public networks or is it a dedicated service for its users? This question is to be addressed in regulation before massive investments are possible.

But also at power system level the impact may be significant and ask for measures. An assessment of National Grid in the UK indicated that peak load is going to increase by some GW to nearly 20 GW, depending on the scenario assumptions [11]. This is a 10% to 30% increase which clearly has implications for generation and transmission adequacy.

Assuming that these limitations might be mitigated just by intelligent charge control is risky. While charge control is inevitable for system optimization it’s impact on the end users experience in terms of availability of the EV has to be balanced very carefully. But also traders are seriously affected by massive actions of network operators due to network congestions. From a market perspective such an influence of network companies on the market result, in general, is highly undesirable.

V. New Technologies and Game Changing Trends

With new technologies new mobility concepts have been proposed. They promise more efficient use of the infrastructure consisting of road, power networks and, in the end, EVs. Already during recent years in urban areas car sharing concepts offering EVs have been successfully implemented. Car sharing increases the utilization of the vehicles. In combination with the autonomous driving, shared EV's allow to allocate the optimum charging infrastructure independent from the end users starting point or destination. The whole 'Robotaxi' fleet can be managed much more flexibly. Respective scenarios have been investigated and show a significant reduction in required vehicles with minor compromises in comfort [12]. Such a vision merges public and individual transportation in an unprecedented manner. In theory it allows a significant reduction of privately owned cars.

Of course, such a scenario has many consequences. Robotaxis are not 100% and immediately available, they introduce some waiting time. Additionally, they do not offer the capability for long distance trips, e.g. family vacation. Feasible and acceptable complementary services for these needs are a precondition for harvesting the benefits of the concept.

In the end, such a 'public' mobility infrastructure has a disruptive impact on the automotive industry. The vehicle market as we knew him will diminish dramatically. This societal change will require attention from policy makers as well

VI. Summary and Conclusions

Technology progress, for example in the field of storage, supports the transformation from ICE vehicles to electro-traction in transportation. However, regulation and policies more than technology will determine speed and direction of future developments. With the right incentives and framework conditions, even in the past, road based E-mobility would have been feasible in various segments. However, the change affects so many areas of society that designing holistic policies and adequately addressing the various conflicting interests is extremely challenging. This transformation is really about a paradigm change, even more than the integration of fluctuating renewable sources.

Electrical infrastructure may or may not become one of the bottlenecks in this change process. Adjustment of this infrastructure takes time. Policy makers rather than engineers have to take the major decisions. This needs a consistent vision and courage to translate that into legal frameworks in an early stage. But also a broad societal and stakeholder participation is key. Otherwise there is a substantial risk that policy will not result in the desired progress or even may fail completely.

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