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The Power of Sharing: More Flexible Power System through Mobility-as-a-Service

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Abstract

An increasing number of European cities are actively supporting Mobility-as-a-Service (MaaS) in order to make the personal transportation system more efficient and to increase the liveability of the cities. MaaS provides an opportunity to expand the market for electric vehicles to everyday users. It also helps to create a more seamless connection between electric vehicles and the power system from the technical, as well as from the economic viewpoint. This will help to exploit the potential of electric vehicles in order to increase flexibility in the power system and to avoid technical occurrences, such as overloads. However, there are still some obstacles in harnessing the best symbiosis between MaaS electric vehicle fleets and smart grid solutions. While some of these obstacles are linked to the markets that are not yet fully generated, there are also obstacles linked to different policies that are yet not supporting these new methods of mobility.

Keywords:

Mobility-as-a-Service, smart grid, electric vehicle integration

Introduction

If the European Union wants to reach its climate targets, emissions from the transportation sector must be reduced drastically. Authorities have plans to increase the share of electric vehicles in order to reach the GHG emission reduction targets and the automotive industry would like to increase their sales in order to meet the binding CO_2 emissions standard in the EU. Nevertheless, something seems to be missing. The most common reasons that make the consumers doubtful about electric vehicles are their relatively high purchase price [1,2], the lack of public charging stations [3–5], range anxiety [6] and a general hesitation towards new technologies [3].

The shift from gasoline and diesel cars to electric vehicles offers an excellent moment to rethink the personal mobility system in urban environments. Instead of replacing the gasoline and the diesel cars with electric-powered ones, the whole system should be made more efficient. It is evident that one emission reduction measure is not able to solve the CO_2 emission targets set by the EU and the national governments, but a mix of various measures is needed, as seen, for example, in the Finnish and German calculations [7–9]. By default, relying strongly on privately owned cars is inefficient as an average car is used only 3 to 4 % of the time [10]. On the other hand, private vehicles occupy relatively large parking areas, which is a concern in urban areas. Providers of charging services do not install charging stations due to the lack of customers and customers don't buy electric vehicles due to the lack of charging stations. Seems as the chicken-and-egg problem. When re-shaping our urban mobility system, we should focus on the efficiency: using instead of owning. Therefore, this would be the most fitting moment to realize the full potential of Mobility-as-a-Service (MaaS) solutions supported by electric vehicles. In addition, there is a lot of unexplored potential in ongoing technological trends of the ICT sector and the increased connectivity that can be applied to the personal transportation to re-shape mobility.

Today, any major city in Europe has a public transport system. Low-cost bus companies are challenging the trains on intercity public transport. Car sharing is trying its breakthrough without exceeding the critical mass in many cities. Ride sharing services are offered but remain unknown to many people. Traditional taxi services have declared war against new mobile applications, like Uber. There are many options for personal transport, but the major problem is that all these services are developed rather independently from each other. All of these modes of transport serve a different purpose and all of them are useful. Otherwise they wouldn't exist. The missing link is a connection between all these services. Offering such services separately from each other is comparable to selling cheese only in the cheese shop, vegetables only in the vegetable shop and fruits only in the fruit shop. Why not create a supermarket of transport where all transport services can be bought in one place, according to the needs of the customer? The personal transport system must be developed as a whole instead of developing each mode of transport in an isolated manner. Making this happen requires collaboration of many different actors, which makes it difficult. Various actors, such as national and local public administrations as well as companies of public transport, automotive, energy and ICT industries, have to collaborate with each other. This change of mind set does not happen without strong support and a unified strategy from the national and local authorities [11].

There are many reasons that have slowed down the implementation of electric vehicles and MaaS. The reasons aren't limited to any certain stakeholders, but require change by all; the users, charging system providers, mobility service providers and policies. Next, we consider some of these reasons and then we aim to show how collaborative service development may result in solutions that benefit the implementation of MaaS and electric vehicles as well as the development of flexible power network.

What is Stopping Us?

Charging stations as business

Charging at home will be most likely the primary mean to power up the car, but at the same time it is crucial to add more and more public charging locations to gain public acceptance [4,12]. Since public charging infrastructure is needed but most of the charging is done at home, it creates a challenging business opportunity, as the actual demand of public charging is hard to estimate and the share of electric vehicles is still small [13,14]. Therefore, policy support for charging should be involved to start of the market, when it may be too risky for charging system providers because of the low number of cars requiring charging. However, it is estimated that within short to medium term, investments to fast charging network would be financially profitable if the share of electric vehicles increases [5,13].

Space used for parking vs. charging

Charging stations with 11 kW or 22 kW of charging power are installed in many cities around Europe. It should not be forgotten that such charging stations require space. In case there were considerably more charging stations in the streets, the space demand for parking areas would also increase. This infrastructure is usually operated by private or semi-public companies. One standalone charging station has installation costs of roughly few thousand euros. In daily driving, the battery is not used close to 0 per cent state of charge, which leads to the fact that typical charging times are usually less than an hour [6]. Some charging operators have a separate price for the parking time and the charged power (for example, 2 €/hour and 0.3 €/kWh) while in other cases, only the charged power is paid by the customer (for example, 0.3 €/kWh). Few operators also provide flat rates. When thinking from the customer viewpoint, the second option is more comfortable, since a private vehicle can be parked as long time as possible if no further limitations for the parking time are set. This has one important disadvantage from the system point-of-view as the charging station is used inefficiently when the parking time exceeds the required charging time. One vehicle not only reserves the charging capacity but also blocks the possibility for charging from other users. This is comfortable for the individual customer, but not efficient use of the whole charging infrastructure.

The first option has the benefit from the system viewpoint that it steers users to park their vehicles for as short time as needed. On the other side, it may not be that pleasant to the users to pay per hour when they are, for instance, working. Neither is the option of relocating the vehicle to another parking place after the battery is fully charged, let's say after 40 minutes, convenient. Generally, people tend to think charging as an alternative to filling up the car with liquid fuel and therefore think they are losing time in the process. However, it creates a new burden for the user if the vehicle should be relocated during a longer stay. The charging behavior should therefore be adapted to a simultaneous task during shopping trips when the car will be parked for a longer period [12]. It is also shown that difficulties in finding a charging point decreases the willingness to use an electric vehicle [15].

High peak electricity needs

An important fact to be considered is that today the peak charging time coincides with the time of peak consumption in low voltage networks. This occurs at early evening when people arrive at home and plug their electric vehicle for charging. Electric vehicles present completely new load on top of all other load in the low voltage network that can be already high even without electric vehicles. Hence, electric vehicles can increase the peak load considerably [16].

Considering the fact that European Union would like to increase the share of electric vehicles in the future means, in practice, that thousands and thousands of public or semi-public charging stations with 22 kW or 11 kW will be installed. If a high percentage of the new electric vehicles will be private, it not only means tremendous costs when installing the charging stations, but also means that the use rate of these charging stations will be very low. In other words, there will be an enormous amount of idle charging capacity.

Another option is to install high-power charging stations (up to 350 kW) that, from the user's perspective, would work as gasoline stations today: charging an electric vehicle within minutes while waiting. The drawbacks are the high prices of the charging stations as well as expensive and limited possibilities of network connections in urban areas. However, their payback time can be reduced when the same charging station is used to other customer groups, such as trucks, buses and taxis.

Number of electric vehicles needed

When thinking about the model of the future transport, both the customer convenience as well as the efficiency of the transport system should be considered. Therefore, the current amount of charging stations would support a launch of electric vehicle (EV) car-sharing solutions by allowing one operator to run both a set of charging points and a car sharing platform to support quick turnaround of cars giving space to the ones that need charging. Since the electricity prices may vary and new demand may create price increases, a car sharing bundled in the form of MaaS offering would also be more comfortable for individual customer, since the bundle price is known in advance and the variations in electricity prices would then affect the service provider.

MaaS as a Source of Demand for electric vehicles

Mobility-as-a-Service (MaaS) is a concept of multimodal transport, where travel from various operators can be booked and paid by using one platform. The approach of MaaS [17] has the power to increase the efficiency of the personal transportation system from both economy as well as energy viewpoints. This means user-oriented, flexible and multimodal transportation, where the user is not tied to one form of transport. The mobile phone operators give users the possibility to not to pay for single minute of call, but to choose between various packages including telephone and internet with the possibilities of roaming through the networks of different operators. Such packages seem to become reality in the transport sector as well. MaaS is a tool for organizing a collaboration between the involved actors rather than provoking detrimental competition: setting the pieces together into one large puzzle. That said, the boundaries of public and private transport become less evident. Without a doubt, shared electric vehicles form a natural part of MaaS in urban areas.

Wider demand for charging

As stated earlier, when developing the future urban transport system, the efficiency is a key concern. Services for purely car sharing have existed for a long period, but the demand has been quite small. Therefore, MaaS seems to offer a perfect way to increase the number of electric vehicle users by providing more seamless user experience through bundling car sharing with other forms of mobility. Then, as electric vehicles are shared, they can be used more efficiently. The same applies to the charging stations as the charging infrastructure will be developed naturally hand-in-hand with the increasing number of electric vehicles. It should be remembered that one of the key factors to increase attractiveness of electric vehicles is a sufficient availability of the charging sites [18–20]. Once potential users do not have to buy their own electric vehicle before they can use it, they have a lower threshold to get familiar with the new technology. In the concept of multimodal transport, the battery of the most cars must not be sized according to the longest holiday travel, while another car or a train can be used for that purpose. When the costs of electric vehicles and charging infrastructure are divided among more users, the customers can afford vehicles of higher quality, which could attract customers and have beneficial impact on road safety. Fleets of shared vehicles provide large amounts of real use data, which helps to develop future mobility concepts or even give input to new transport policies [21,22]. Also, shared vehicles offer a platform to test and promote new car models. Anyway, since cars are used more, they must be renewed more often. MaaS offers automotive industry new markets in the form of digital and non-digital services [23]. This needs more collaborative business models with other actors, such as the charging providers. Data and payment exchange between these different businesses working as one for the end-user of MaaS should be enabled and kept simple. Also, a service of shared electric vehicles could be started with lower initial costs through MaaS than as a completely standalone service [24]. This is because it is naturally connected with other modes of transport, which means that the service of shared electric vehicles can focus, at least at the starting phase of the business, on the locations where most customers are, and then expand the business.

Benefits for power infrastructure

Along with the enrolment of electric vehicles, cars will become an integrated part of the future power system and are able to provide various services to the power system operator [25,26]. Charging stations are the points where the power and transport network connect physically. Mutual support from these two systems can be found [27]. However, the detrimental effect of large fleets of electric vehicles hit heavily to the low voltage part of the supply grid [28,29]. In other words, when a large number of electric vehicles is charged simultaneously from the same electricity distribution network, overloading or voltage drops are possible secondary effects, among others. Proactive, or smart, charging algorithms can be introduced in order to:

1. control the charging process during
    a. normal operation (for example, charge during the hours of the lowest prices on the electricity market),
    b. abnormal operation (for example, reduce the charging current when part of the low voltage network is close to a congestion) and
2. provide new services to the power system.

When only charging algorithms are not enough to provide charging of sufficient quality, another possibility is to invest in additional hardware. For example, in a stationary battery energy storage [30] the energy storage acts as a power buffer between the distribution network and electric vehicles. The idea is that during moments of peak load, part of the power required by electric vehicles is fed from the distribution network and part from the energy storage. This can help to postpone investments in network reinforcements. An energy storage can be harnessed with several functions and offer services also to the distribution network. For example, the battery can be charged during the hours of the lowest electricity prices and to provide peak shaving to the distribution transformer.

New business opportunities

Within MaaS, private users could also share their electric vehicles (Peer2Peer Car Sharing) or a charging station (Plug Sharing) to reduce the fixed costs of car ownership. This is equivalent to prosumerism in power systems: offering transport services (instead of offering energy in power systems) in a micro-scale. However, there is still need to support these types of services, which differ from a regular car use. For example, the insurance packages provided normally do not usually allow renting of the vehicle, meaning new packages and solutions should be presented for the market. There is also some other matters that need to be taken into account, such as how Peer2Peer car and electricity could be taxed correctly, while being easy enough for the provider.

In the minds of many consumers, electric vehicles have the benefit of being an exciting and an environmentally responsible mobility solution [3,31]. This combined with silent driving experiences, the change of ownership towards a less materialistic direction and the freedom-of-choice between various transport modes can be perceived as modern and appealing within many customer groups [3,32,33].

Newer technologies for shared fleet

Once more, when the costs related with electric vehicles are shared among many users, it is possible to invest in more sophisticated and expensive technologies, such as intelligent charging or stationary battery energy storages. This, in turn, increases the flexibility of the whole power system and makes new network services, like vehicle-to-grid, easier to put into practice. From the administrative viewpoint, it is much easier to operate a fleet of electric vehicles owned by one operator rather than trying to convince thousands of individual customers to “rent” their batteries to be used for the power system. This is one remarkable benefit of MaaS when talking about vehicle-to-grid services. More flexibility in the future power systems means that a higher share of intermittent renewable energy can be accommodated. A further benefit is that more flexibility also means increased robustness in the power system.

Vehicle-to-grid

New network services, such as vehicle-to-grid provides possibilities for electric vehicles to support the whole power system against frequency deviations. In case of a frequency drop, vehicles can inject stored power from their batteries to the network and, in case of a too high frequency, the charging of electric vehicles can be carried out with higher power. Additionally, this would enable electric vehicles to operate as sub-aggregators in the electricity market [34,35]. With shared vehicles, strategies of vehicle-to-grid are easier to realize from the technical as well as from the administrative viewpoint. This is due to the fact that one fleet operator owns many vehicles. Thus, only one contract between the fleet operator and the distribution or the transmission system operator results in significant amount of power capacity instead of making separate contracts with hundreds or thousands of private customers. The practical control of the vehicles will be easier due to the reduced selection of vehicle and charger models. It is also a recognized hinder for vehicle-to-grid applications that many private owners of electric vehicles would be unwilling to let someone to use the battery of their electric vehicle in order to support power network. This issue would be removed when the vehicles are owned by a fleet operator.

Controlling charging processes of fleets rather than focusing only on individual vehicles offers more flexibility to the power system operation. When a customer owns a private vehicle, he or she is tied to one particular vehicle. Instead, if a customer can choose any amongst 20 available electric vehicles in a parking area of shared vehicles, he or she can be recommended to select the vehicle with the highest state-of-charge of the battery. To increase the level of intelligence of the parking area, the controller of the charging processes (in that particular parking area of 20 electric vehicles) can be equipped with an additional machine learning algorithm that can make statistical conclusions of the arrival and leaving times of the vehicles. To put it in other words, the algorithm can learn the load behavior of the charging area. Based on this, the algorithm will be able indicate (with some error margin) how many vehicles must be charged at a certain time of the day and a certain day of the week. Knowing the needs of the customers permits using the charging and the battery capacity of the electric vehicles more cost-effectively and can release capacity from the power network. When charging power within one parking area can be directed only to the number of vehicles that is needed instead of trying to charge all vehicles as quickly as possible, battery capacity can be reallocated to other tasks, such as vehicle-to-grid services. Furthermore, a possibility to reserve a vehicle in advance can make the charging even more precise. Serving the users of electric vehicles more accurately could result in improved customer experience. So, both the power system operator as well as the drivers could benefit from the increased level of intelligence.

For example, the algorithm of the charging controller can indicate that 6 out of 20 vehicles must be fully (or nearly fully) charged at 6 P.M. In case of 20 vehicles, it is possible that not all vehicles can be provided with full charging power simultaneously due to the limitations in the low voltage network, especially during the daily peak hours of power demand. As previously mentioned, in Germany, nominal power of a public charging station is typically 22 kW. Charging 20 cars with 22 kW means 440 kW of power, which is a lot for a typical German low voltage network. In this case, if the available charging power from the network is, let's say, 220 kW (50 per cent from 440 kW) and if the algorithm indicates that 6 vehicles must be charged by 6 P.M., then, full charging power (22 kW per vehicle) can be directed to 6 vehicles (132 kW), instead of charging 20 vehicles at half power (11 kW/vehicle * 20 vehicles = 220 KW). In this case, 88 kW (220 kW – 132 kW = 88 kW) of the network and battery capacity, could be released to other network services.

One innovative example of how electric vehicles can be used to absorb more power from intermittent renewable sources is remote self-consumption [36]. Consuming excessive power from the network, for example, due to a sudden increment of the output power from intermittent power sources, works only if there is reserve margin left in the charging process. If all vehicles are charged with full power already, the charging power cannot be further increased. In a case that the power network cannot offer enough charging capacity, energy can be shared between the vehicles. This means that the battery of, let's say one vehicle, is charged from five other vehicles for example. This can be done to make sure that the required number of fully charged vehicles will be available when needed.

Supportive policies for development

Mobility-as-a-Service with shared electric vehicles seems to offer more flexibility to the users in the form of multimodal transport and pricing schemes customized to the needs of the user. At the same time, it has the potential to provide more flexibility to support the power system. The public administration has much to do in order to set policies that encourage companies to build market models around MaaS–type concepts. Likewise, the end customers must realize their possibilities in new multimodal transport concepts so that the new services can be created as customer–oriented as possible.

Electricity tariffs play an important role in the decision whether fleet operators decide to use potential of electric vehicles in network flexibility or not [37]. Therefore, new network tariffs should be designed so that they encourage, or at least do not discourage, the use of this capacity that will be anyway plugged in the network [38]. The ability of charging electric vehicles according to several objectives, makes the design of both charging and fare tariff schemes complicated [39]. Thus, bundled tariffs that make a compromise between several sub-objectives should be found [40]. At the end, creating charging schemes and tariffs too much oriented to the network use may result in customer dissatisfaction. That is why the customer dissatisfaction caused by postponed charging should be reflected in the policies [16].

Conclusion

Through the increasing number of electric vehicles, the power and transport networks become more connected than ever. On the one side, the transport sector becomes more dependent on the electricity network. On the other side, electric vehicles can make the power system more flexible by means of energy storage capacity. Mobility-as-a-Service (MaaS) appears to be an adequate tool to increase the efficiency of the urban transport and to give a boost for the implementation of electric vehicles. Higher efficiency of transport can be gained in terms of both economy and energy.

Using electric vehicles through the MaaS-model offers benefits for the power system over the use of privately-owned ones. MaaS permits financing electric vehicles and the charging infrastructure among more users, which reduces the fixed costs. This does not only mean that electric vehicles can be more affordable to the final consumers, but also that they, as well as the charging infrastructure, can be equipped with more advanced and expensive technologies. Such increased level of intelligence opens the way for vehicle-to-grid services. Since the users are not attached to certain vehicles, the users can be directed to use vehicles in a way that is beneficial for the power system. This could be achieved without compromising the comfort of the users. At the same time, these shared cars would also park and charge mostly inside a known and limited area and the rotation of shared vehicle fleet can be better estimated compared with fleets of private cars. This would support the building and investing on new vehicle services to make the electric vehicle-system more efficient.

In general, these benefits could also be gained through large fleets of shared electric vehicles without actually bundling it with MaaS solutions. These types of services exist already, but they have not had a major market share in terms of developing energy grid systems around them. Hence, the development of MaaS offers a viable solution to offer shared electric vehicles as a part of the whole mobility solution for the users, making the end-product more attractive. Making the use of electric vehicles as a part of the MaaS-system would also benefit the business, since they can gain more specific information about the mobility needs of the users regardless of the transport mode and use this to better tailor and balance the EV use and load factors. Centralized information from one MaaS-system consisting of thousands of charging stations, could provide information to help the planning of the power distribution network. Without a concentrated hub of information, it is difficult to gather all dispersed data as a meaningful entity.

It is generally known that the capacity of the low voltage network poses major limitations to the charging of electric vehicles. One key aspect of enabling network services, such as vehicle-to-grid, is to use the charging power as accurately as possible: not using more network capacity than required by the transportation needs. When the network capacity is the limiting factor, the operation of the charging stations should be optimized and the network capacity used as efficiently as possible.

Policies and tariffs have a leading role in making the potential of MaaS in the power system as an attractive market opportunity to the sub-aggregators and the fleet operators. The cross-section of two major sectors, electricity and transport, create rather complex circumstances to the policy makers due to the large number of actors with diverse interests.

As a bottom line, MaaS gives a feasible framework for the shared electric vehicles in cities, which is reflected as increased flexibility in the power system operation. Thus, it can be said that MaaS can help to integrate more power from the intermittent sources of renewable energy. MaaS can make the sectors of electricity and transport to gain mutual benefits in a natural and customer-oriented way, while making our urban environments more livable and sustainable.

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References

1. Moon S, Lee D-J. An optimal electric vehicle investment model for consumers using total cost of ownership: A real option approach. *Appl Energy*. 2019;253:113494. doi:https://doi.org/10.1016/j.apenergy.2019.113494
2. Ghasri M, Ardeshiri A, Rashidi T. Perception towards electric vehicles and the impact on consumers’ preference. *Transp Res Part D Transp Environ*. 2019;77:271-291. doi:https://doi.org/10.1016/j.trd.2019.11.003
3. Ingeborgrud L, Ryghaug M. The role of practical, cognitive and symbolic factors in the successful implementation of battery electric vehicles in Norway. *Transp Res Part A Policy Pract*. 2019;130:507-516. doi:https://doi.org/10.1016/j.tra.2019.09.045
4. Bi R, Xiao J, Viswanathan V, Knoll A. Influence of charging behaviour given charging infrastructure specification: A case study of Singapore. *J Comput Sci*. 2017;20:118-128. doi:https://doi.org/10.1016/j.jocs.2017.03.013
5. Morrissey P, Weldon P, O’Mahony M. Future standard and fast charging infrastructure planning: An analysis of electric vehicle charging behaviour. *Energy Policy*. 2016;89:257-270. doi:https://doi.org/10.1016/j.enpol.2015.12.001
6. Melliger MA, van Vliet OPR, Liimatainen H. Anxiety vs reality – Sufficiency of battery electric vehicle range in Switzerland and Finland. *Transp Res Part D Transp Environ*. 2018;65:101-115. doi:https://doi.org/10.1016/j.trd.2018.08.011
7. Särkijärvi J, Jääskeläinen S, Lohko-Soner K. *Toimenpideohjelma Hiilettömään Liikenteeseen 2045 - Liikenteen Ilmastopolitiikan Työryhmän Loppuraportti*.; 2018.
8. Liimatainen H, Pöllänen M, Viri R. CO2 reduction costs and benefits in transport: socio-technical scenarios. *Eur J Futur Res*. 2018;6. doi:10.1186/s40309-018-0151-y
9. BMU. *Climate Action in Figures*. Berlin; 2019. https://www.bmu.de/en/publication/climate-action-in-figures-2019/.
10. Bates J, Leibling D. *Spaced Out - Perspectives on Parking Policy*. London; 2012. https://www.racfoundation.org/assets/rac_foundation/content/downloadables/spaced_out-bates_leibling-jul12.pdf.

11. Rotgang A. The Role of Public Administration in Supporting Electric Vehicles within Mobility-as-a-Service Model. 2019.

12. Philipsen R, Schmidt T, Ziefle M. A Charging Place to Be - Users' Evaluation Criteria for the Positioning of Fast-charging Infrastructure for Electro Mobility. *Procedia Manuf*. 2015;3:2792-2799. doi:https://doi.org/10.1016/j.promfg.2015.07.742

13. Serradilla J, Wardle J, Blythe P, Gibbon J. An evidence-based approach for investment in rapid-charging infrastructure. *Energy Policy*. 2017;106:514-524. doi:https://doi.org/10.1016/j.enpol.2017.04.007

14. Viswanathan V, Zehe D, Ivanchev J, Pelzer D, Knoll A, Aydt H. Simulation-assisted exploration of charging infrastructure requirements for electric vehicles in urban environments. *J Comput Sci*. 2016;12:1-10. doi:https://doi.org/10.1016/j.jocs.2015.10.012

15. Daina N, Sivakumar A, Polak JW. Modelling electric vehicles use: a survey on the methods. *Renew Sustain Energy Rev*. 2017;68:447-460. doi:https://doi.org/10.1016/j.rser.2016.10.005

16. Argade SG, Aravinthan V, Büyüktahtakın IE, Joseph S. Performance and consumer satisfaction-based bi-level tariff scheme for EV charging as a VPP. *IET Gener Transm Distrib*. 2019;13(11):2112-2122. doi:10.1049/iet-gtd.2018.5754

17. Liimatainen H, Mladenović MN. Understanding the complexity of mobility as a service. *Res Transp Bus Manag*. 2018;27:1-2. doi:https://doi.org/10.1016/j.rtbm.2018.12.004

18. Bauer GS, Phadke A, Greenblatt JB, Rajagopal D. Electrifying urban ridesourcing fleets at no added cost through efficient use of charging infrastructure. *Transp Res Part C Emerg Technol*. 2019. doi:10.1016/j.trc.2019.05.041

19. Mounce R, Nelson JD. On the potential for one-way electric vehicle car-sharing in future mobility systems. *Transp Res Part A Policy Pract*. 2019. doi:10.1016/j.tra.2018.12.003

20. Bjerkan KY, Nørbech TE, Nordtømme ME. Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway. *Transp Res Part D Transp Environ*. 2016. doi:10.1016/j.trd.2015.12.002

21. Paffumi E, De Gennaro M, Martini G. Alternative utility factor versus the SAE J2841 standard method for PHEV and BEV applications. *Transp Policy*. 2018;68:80-97. doi:https://doi.org/10.1016/j.tranpol.2018.02.014

22. Paffumi E, De Gennaro M, Martini G. European-wide study on big data for supporting road transport policy. *Case Stud Transp Policy*. 2018;6(4):785-802. doi:https://doi.org/10.1016/j.cstp.2018.10.001

23. Athanasopoulou A, de Reuver M, Nikou S, Bouwman H. What technology enabled services impact business models in the automotive industry? An exploratory study. *Futures*. 2019;109:73-83. doi:https://doi.org/10.1016/j.futures.2019.04.001

24. Cooper P, Tryfonas T, Crick T, Marsh A. Electric Vehicle Mobility-as-a-Service: Exploring the "Tri-Opt" of Novel Private Transport Business Models. *J Urban Technol*. 2019;26(1):35-56. doi:10.1080/10630732.2018.1553096

25. Arias NB, Hashemi S, Andersen PB, Træholt C, Romero R. Distribution System Services Provided by Electric Vehicles: Recent Status, Challenges, and Future Prospects. *IEEE Trans Intell Transp Syst*. 2019:1-20. doi:10.1109/TITS.2018.2889439

26. Nimalsiri NI, Mediwaththe CP, Ratnam EL, Shaw M, Smith DB, Halgamuge SK. A Survey of Algorithms for Distributed Charging Control of Electric Vehicles in Smart Grid. *IEEE Trans Intell Transp Syst*. 2019:1-19. doi:10.1109/TITS.2019.2943620

27. Calvillo CF, Sánchez-Miralles Á, Villar J. Synergies of Electric Urban Transport Systems and Distributed Energy Resources in Smart Cities. *IEEE Trans Intell Transp Syst*. 2018;19(8):2445-2453. doi:10.1109/TITS.2017.2750401

28. Pirouzi S, Aghaei J, Niknam T, Farahmand H, Korpås M. Proactive operation of electric vehicles in harmonic polluted smart distribution networks. *IET Gener Transm Distrib*. 2018;12(4):967-975. doi:10.1049/iet-gtd.2017.0875

29. Zahedmanesh A, Muttaqi KM, Sutanto D. Direct Control of Plug-In Electric Vehicle Charging Load Using an In-House Developed Intermediate Control Unit. *IEEE Trans Ind Appl*. 2019;55(3):2208-2218. doi:10.1109/TIA.2018.2890786

30. Yan Q, Zhang B, Kezunovic M. Optimized Operational Cost Reduction for an EV Charging Station Integrated With Battery Energy Storage and PV Generation. *IEEE Trans Smart Grid*. 2019;10(2):2096-2106. doi:10.1109/TSG.2017.2788440

31. Axsen J, Sovacool BK. The roles of users in electric, shared and automated mobility transitions. *Transp Res Part D Transp Environ*. 2019;71:1-21. doi:https://doi.org/10.1016/j.trd.2019.02.012

32. Ensslen A, Gnann T, Jochem P, Plötz P, Dütschke E, Fichtner W. Can product service systems support electric vehicle adoption? *Transp Res Part A Policy Pract*. 2018. doi:https://doi.org/10.1016/j.tra.2018.04.028

33. Esztergár-Kiss D, Kerényi T. Creation of mobility packages based on the MaaS concept. *Travel Behav Soc*. 2019. doi:https://doi.org/10.1016/j.tbs.2019.05.007

34. Yao E, Wong VWS, Schober R. Optimization of Aggregate Capacity of PEVs for Frequency Regulation Service in Day-Ahead Market. *IEEE Trans Smart Grid*. 2018;9(4):3519-3529. doi:10.1109/TSG.2016.2633873

35. Vatandoust B, Ahmadian A, Golkar MA, Elkamel A, Almansoori A, Ghaljehei M. Risk-Averse Optimal Bidding of Electric Vehicles and Energy Storage Aggregator in Day-Ahead Frequency Regulation Market. *IEEE Trans Power Syst*. 2019;34(3):2036-2047. doi:10.1109/TPWRS.2018.2888942

36. Maasmann J, Rettberg JF, Rehtanz C, Schmutzler J, Gröning S, Wietfeld C. SyncFueL - Concept of Remotely Synchronized Own-Consumption for Charging Electric Vehicles. In: *2015 IEEE PES Innovative Smart Grid Technologies Latin America (ISGT LATAM)*. ; 2015:552-557. doi:10.1109/ISGT-LA.2015.7381214

37. Mäkinen S, Valta J, Kotilainen K, Saari U. Prosumers' Digital Business Models for Electric Vehicles: Exploring Microfoundations for a Balanced Policy Approach. In: *Digital Business Models - Driving Transformation and Innovation*. Palgrave Macmillan, Cham; 2019. doi:https://doi.org/10.1007/978-3-319-96902-2_9

38. Huber J, Richter B, Weinhardt C. Are Consumption Tariffs Still Up-to-Date? an Operationalized Assessment of Grid Fees. In: *2018 15th International Conference on the European Energy Market (EEM)*. ; 2018:1-5. doi:10.1109/EEM.2018.8469847

39. Huang S, Wu Q. Dynamic Tariff-Subsidy Method for PV and V2G Congestion Management in Distribution Networks. *IEEE Trans Smart Grid*. 2019;10(5):5851-5860. doi:10.1109/TSG.2019.2892302

40. Mouli GRC, Kefayati M, Baldick R, Bauer P. Integrated PV Charging of EV Fleet Based on Energy Prices, V2G, and Offer of Reserves. *IEEE Trans Smart Grid*. 2019;10(2):1313-1325. doi:10.1109/TSG.2017.2763683