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# My eDrive – Simulating Electric Vehicles Using a Smartphone

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**Abstract**

Electric vehicle concepts are diverse and pose challenges to potential customers, particularly in terms of suitability estimation, expected costs and environmental benefit in real-life operation. The project “My eDrive” aims to provide these customers with an effective decision-making support. Using a smartphone app, salable EVs can be simulated for the user’s individual mobility profile. The app has been evaluated in an extensive field test in order to align the concept with customer expectations. This paper gives insight in results of the field test and lessons learnt as well as providing an outlook on the future perspective of consumer counseling in the emerging market for electric vehicles.

Keywords: education, GPS, range, simulation, state of charge

## 1 Background

So far, many people knew electric cars only from the discussion in the media. Today, however, they are increasingly present on the market. The vehicle concepts and models are diverse and pose a challenge for potential customers:

- Is there an electric car that fits my needs?
- Is a purchase financially attractive for me?
- What is the environmental advantage of an electric car in my specific use case?

Uncertainties exist mainly because of high up-front costs and resale price risks, as well as the limited electrical range of the vehicles [1]. Uncertainties about the range are increased by the communication of standardized consumption and driving range values, which can differ from the practical experience considerably.

## 2 Approach and Software

In order to answer the above mentioned questions, the project My eDrive aims to provide potential buyers of electric vehicles with an effective decision-making support: suitable electric vehicles are presented based on the individual usage profile and considering realistic energy consumption values.

A technical framework was chosen where the calculations are done within a server backend which exposes an application programming interface in order to communicate with both a browser-based web interface and a smartphone app (see Figure 1).

- Trip profiles are recorded using GPS of a smartphone app while using a conventional vehicle.
- Subsequently, the track data are then transferred to the server backend on which energy consumption and battery state of charge for the chosen vehicle are calculated using a physical vehicle simulation model based on Matlab©/Simulink©.

Background data for vehicle specific modelling of energy consumption and cost estimates are largely based on databases maintained by the ADAC (General German Automobile Club). The results are then transmitted back to the smartphone app or web interface.

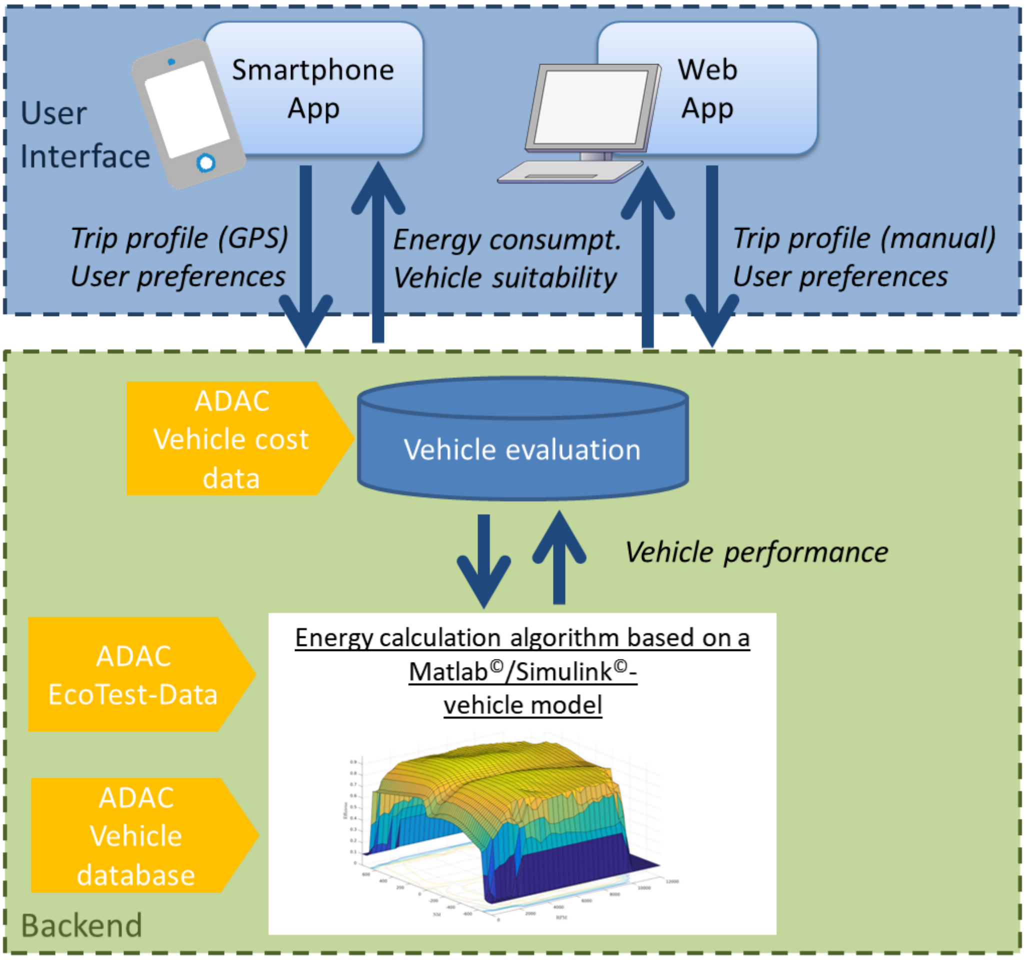


Figure 1: Schematic diagram of the My eDrive Application

**Before Driving:** When starting the app for the first time, users are guided through an e-mobility quick check and asked to enter their current annual mileage, fuel type and average consumption (Figure 2, left). Afterwards a selection of available vehicles is presented which also indicates the $CO_2$ savings potential compared to the user’s current vehicle (Figure 2, middle).

After selecting a vehicle for a virtual test drive, the dashboard (Figure 2, right) shows the virtual state of charge and offers the possibility to either record new trips or enter trips manually. Furthermore it is indicated which share of the personal annual mileage is covered by the trips that have already been recorded or manually entered so far. This gives an impression of how representative these trips are for the overall personal driving profile.

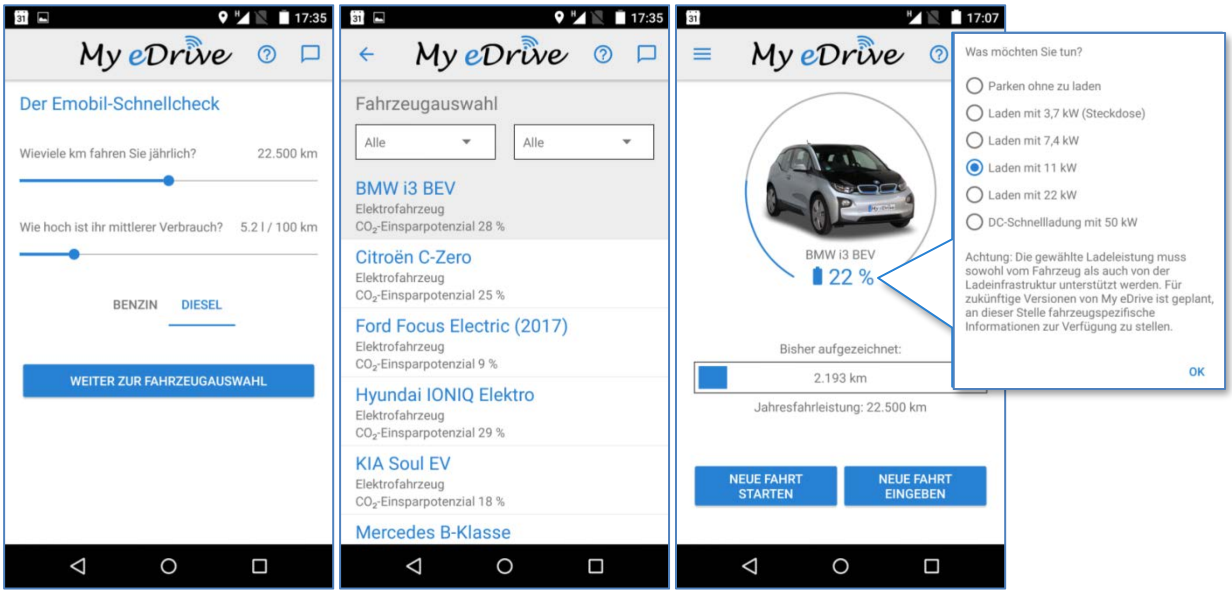


Figure 2: My eDrive App **before driving**:
Emobility quick check (left), vehicle selection (middle) and dashboard with selection of charging mode (right)

**While Driving:** While recording the GPS coordinates and the speed profile of a trip, several real time parameters are displayed as if the user was driving the actual electric vehicle, which are current speed, recorded trip length, state of charge and remaining driving range (Figure 3, left). During trips, the charging infrastructure within a certain radius can be displayed in a map and thus helps to evaluate the suitability of the personal routes for electric vehicles (Figure 3, middle). Between trips, the selected vehicle can be "virtually charged" with choice between several charging powers (Figure 2, far right). This way a potential buyer can get a realistic impression of the day-to-day life with an electric vehicle. As alternative to the GPS based recording, trips can also be entered manually by specifying the starting point, starting time and destination. Trip distance, duration and road type are afterwards automatically calculated (Figure 3, right).

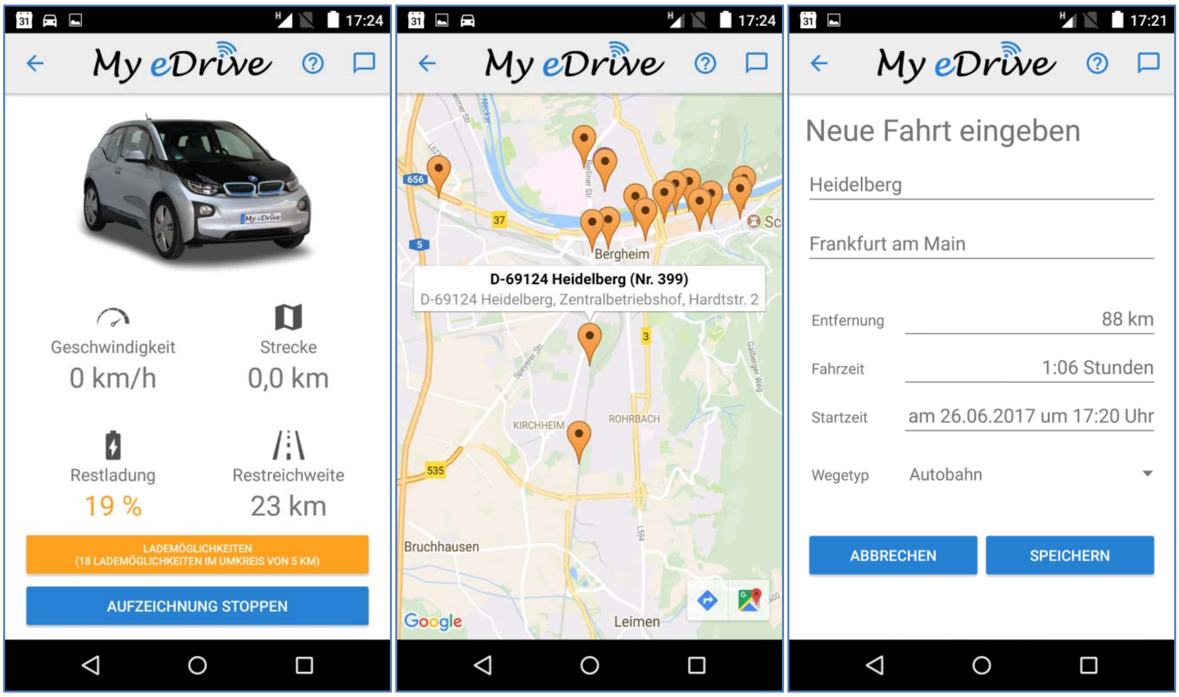


Figure 3: My eDrive App **while driving**: trip recording with instant display of remaining charge and range (left), nearby charging infrastructure (middle) and manual trip entry (right)

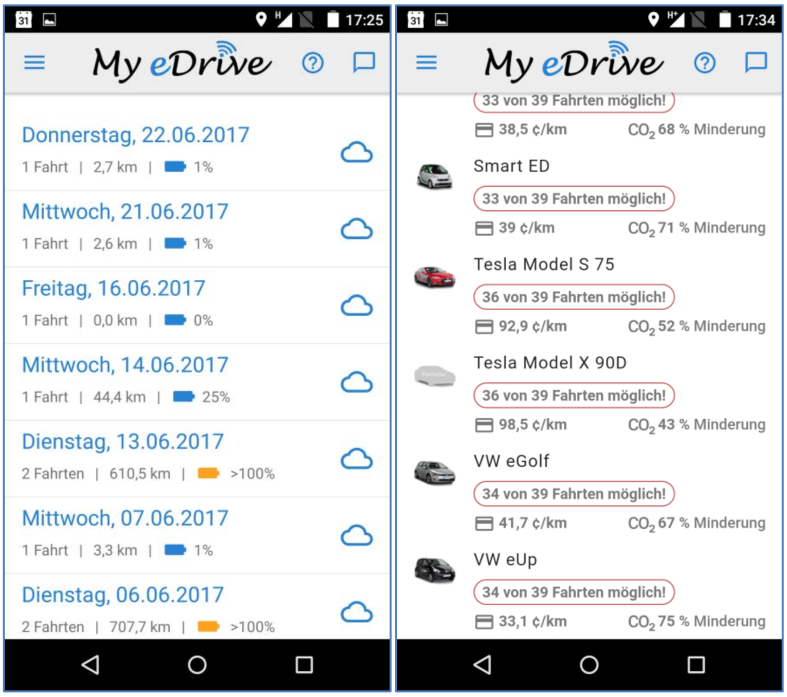


Figure 4: My eDrive App **after driving:**
trip overview with battery consumption for each trip (left) and individual results for each vehicle (right)

**After Driving:** After saving a trip, it will be displayed in the trip overview (Figure 4, left). For all trips also a detailed map based view is available. Besides trip duration and length also average speed and electricity consumption as share of total battery capacity are displayed. The trip overview includes GPS-recorded as well as manually entered trips.

After recording or entering a sufficient number of trips, an evaluation of the suitability, specific costs and $CO_2$ emissions can be displayed. This evaluation is not restricted to the selected virtual test drive vehicles, but is displayed for all vehicle models implemented in My eDrive (Figure 4, right). Hence, it is possible for the user to compare different EVs and this enables him to choose the most suitable car.

The calculation of the specific energy consumption for different vehicle models, is done with a vehicle simulation tool based on Matlab©/Simulink© which is documented in detail in [2]. With this tool, a parameter-based modelling of longitudinal dynamics is performed which considers all relevant resistances such as acceleration, aerodynamic drag, rolling resistance and slopes. Characteristic technical parameters are for instance tare, motor power, nominal torque and the corresponding engine speed, transmission data, maximum velocity, battery capacity and wheel size. The model can take arbitrary driving cycles (speed and slope over time) in order to calculate corresponding loads at the drive shaft. Subsequently, energy consumption and recuperation is derived using engine maps based on efficiency and capacity characteristics of the drivetrains.

Auxiliary consumers such as air-conditioning, light and sound systems are relevant additional energy consumers and are therefore taken into account. Especially heating and air-conditioning is more critical for EVs because of the limited energy storage capacity of the battery and therefore adverse effects on the driving range. Furthermore, conventional vehicles largely use waste heat from the engine for cabin heating. The peak load of electric air condition systems is up to 5-6 $kW_{el}$ while cars need to be heated and cooled during a large share of total driving time. Parameters such as the proportion of re-circulated air, solar irradiation and heat transfer coefficients are input parameters for the estimation of the energy demand for air-conditioning.

The parameters used for each vehicle model are calibrated against the electric driving range derived from the NEDC type approval values and are validated against the results of the ADAC EcoTest. The simulation model delivers reliable results for energy consumption of modelled vehicles in different driving cycles, as shown in [2]. Hence, the model enables the user of My eDrive to have a vehicle specific estimate of the specific energy consumption depending on his individual driving style and ambient conditions. Eventually, vehicle costs and environmental impact stated in My eDrive are based on the model's results.

# 3 Results of the Field Test

To ensure the functionality and to assess the user perception of My eDrive, an extensive field test with registered users has been undertaken from mid-2016 to mid-2017 which was organized based on a dedicated website [3]. Relevant questions for the field test have been:

- Are all essential parameters covered?
- Is the implementation technically robust?
- Is the handling of the tool simple enough to reach beyond technology focused users?

Prior to installation of the app, potential users needed to fill out an initial survey questionnaire. During the field test, the smartphone app, web interface and calculation algorithms were constantly updated following the progress of development. Testers could also continuously comment on features and report bugs using a feedback feature within the app. In total 693 persons initially registered for the beta test and installed the app on their smartphones. Overall, My eDrive test persons use more recently released smartphones than average (see Figure 5) and thus can be considered technology-oriented. This has to be kept in mind when interpreting the following results.

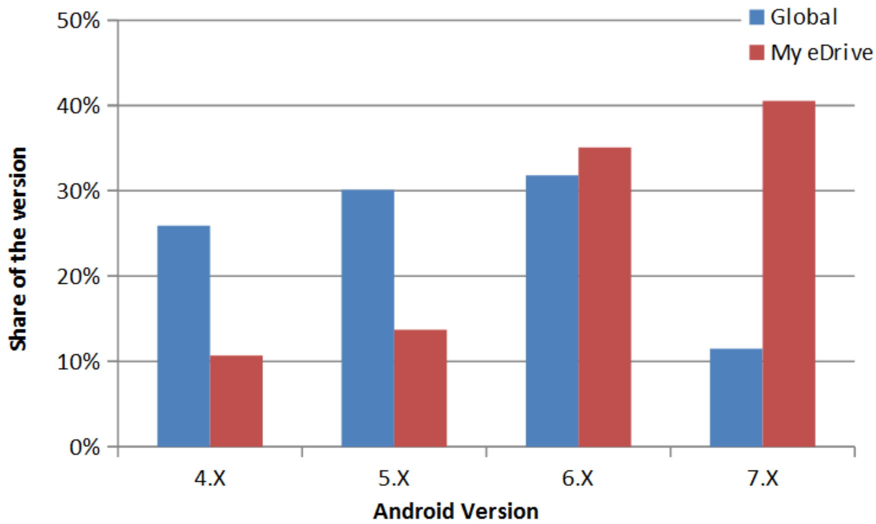


Figure 5: Used Android versions globally and in the field test

At the end of the test period all participants were asked to fill out an evaluation questionnaire, 95 complied with this request. The assessment of the app presented here is mainly based on those answers but also on statistical metadata recorded by the My eDrive server.

Information about the app and the field test was disseminated via a dedicated website [3]. In addition, it was mentioned on the facebook site of the project partner ADAC (German automobile club). There was some media coverage too, most notably in a popular scientific TV show in Germany [4]. Many registrations for the field test can be related to media coverage.

Figure 6 exhibits the number of recorded trips and the mileage per trip. In total 453 users completed more than one trip. About 50% of all participants used the app more than ten times for recording trips. It can be observed that the average mileage per trip drops significantly if more trips are recorded. Users with less than five recorded trips drove in total 43 kilometres whereas intensive users had an average trip length of 33 kilometres. Many users reported that it has been difficult for them to remember to activate tracking at the beginning of a trip. Thus, a reason for shorter average trip length of intensive users could be the fact that they were more aware of the app and remembered to switch on tracking also for “negligible” trips.

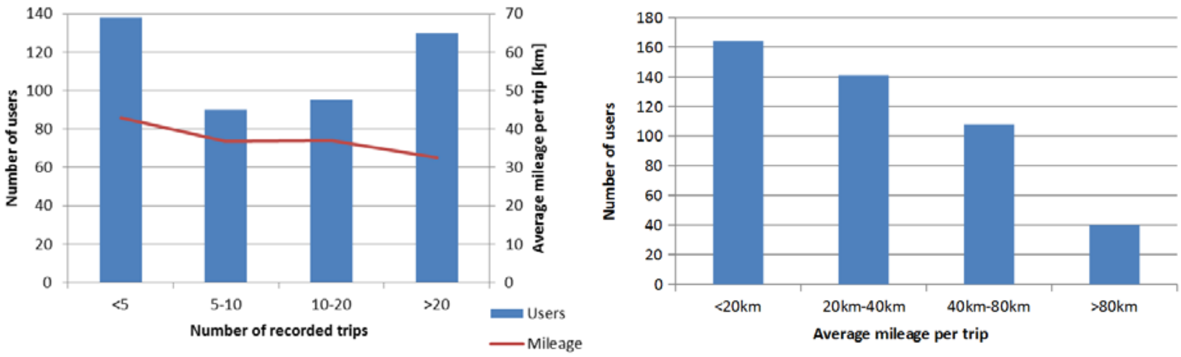


Figure 6: Number of recorded trips per user and average mileage per trip

A closer look unto the trip distances suggests that the average trip distances for most users are well within the range of current EV models (Figure 6, right): More than 91% had average trip lengths of up to 80 kilometres. Only 9% used the car regularly for long distances above 80 kilometres. Of course, EV suitability cannot be sufficiently evaluated using average distances. Future work will include a more in-depth analysis of trip length distributions among users.

Within the app, users were able to choose their virtual test vehicle among 18 battery electric vehicles of which 3 had been added in the course of the test. Figure 7 shows how often the available vehicle models have been chosen as virtual test vehicle: The BMW i3, Renault ZOE Z.E., Tesla Model S 75 and Hyundai IONIQ have been selected most often. The reasons for that have not yet been deeply investigated, but it can be noted that these vehicles have certain unique technical features (high driving range in the case of Tesla, carbon chassis in the case of BMW i3) and/or have been extensively covered by the German media. Generally, an up to date choice of test vehicles was deemed highly important by the users. Frequently, users even requested announced but yet available vehicles.

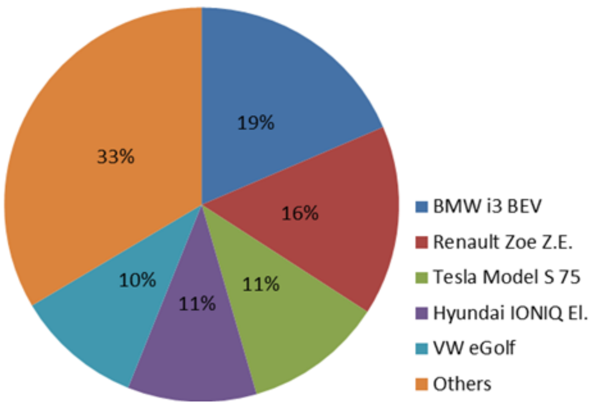


Figure 7: Most selected vehicles in the field test

While the data presented above originate from usage statistics, we now turn to the evaluation of the users’ opinions on the app. 13.7 % of all registered users responded to the final questionnaire, the majority of them recorded more than 20 trips whereas only 18% had five or less trip recordings. Thus, most of the respondents have had sufficient interaction with the app to express a well-founded opinion. Being asked about the comprehensibility of different aspects of the application (see Figure 8), most participants stated to have understood the instructions and options within the app. Particularly the quick check, which gives a preliminary estimation of $CO_2$ reduction potential according to basic usage parameters, was deemed intuitive. The overall concept of the user interface can therefore be regarded as mature, while various details still could be improved according to more specific personal user feedback.

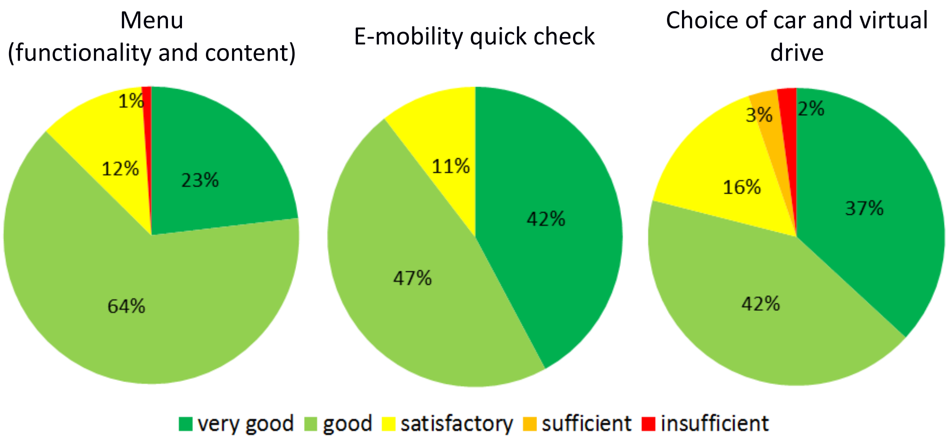


Figure 8: Comprehensibility of My eDrive smartphone application

The dissemination activities within the My eDrive project focused on the smartphone app. However, upon registration, people were also pointed to the web interface of the My eDrive application, which provides additional options and views for result presentation. In the survey, 42% of the participants indicated that they did use the web interface. Hence, a preference towards the sole use of the smartphone for the analysis is observable, though it is possible that more visible references to the web interface or a closer integration of both platforms would make the web interface more attractive.

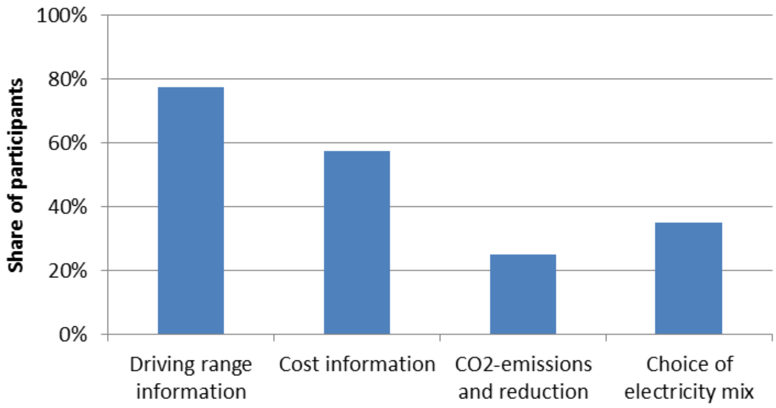


Figure 9: Importance of information provided by the web app (multiple choices possible)

Users of the web interface were asked about the relative importance of the presented information regarding costs, environmental impact and maximum range (Figure 9). Most respondents (about 78%) regard information about the driving range important. This highlights the uncertainty of the consumer towards the issue of the limited range. The cost estimation is also seen as relevant. In contrast, the $CO_2$-emission reduction is of lower relevance to the user. A reason might be that emissions are an abstract entity with no noticeable impact on the consumer. Furthermore we assume that most people who are interested in electric vehicles take the environmental benefit for granted and thus are most interested in their personal hurdles for using them (essentially costs and range).

To capture the overall perception of the app, participants were asked if the app met their expectations. About 80% of the users deemed the application satisfactory in terms of the expectations they had. Though it was not further investigated which exact expectations the users had, it is assumed they are in line with purpose of the app as described in the dissemination activities: informing the user and giving him a tool for decision making based on the suitability of EVs for his personal mobility profile.

A further interesting aspect is the influence of app usage on the purchase intention of the user. The participants were asked before and after the field test about their intention of buying an EV. 49 users answered this question in both surveys. Figure 10 displays the purchase intention of users which were indifferent at the beginning of the field test whether they want to buy an electric car or not after using the app.

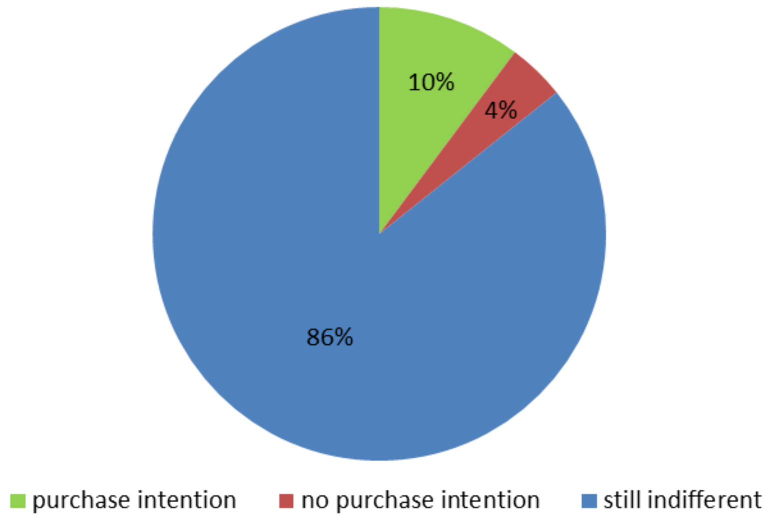


Figure 10: Final purchase intention of initially indifferent participants (49 users)

The majority was still indifferent at the end of the field test, thus their tendency could not be significantly influenced by the application. A reason might be that not all factors which are important for decision making are included in the app. Aspects such as design, interior or space are not considered in the app but have a major influence on the consumer's choice. Moreover, the choice of vehicles within the app was still limited and several vehicle models which entered the market during the field test could not be integrated into the app. It was also clearly stated that the app was still under development and the presented results should be considered with care.

Nevertheless, 14% actually did make a decision towards EVs in the course of the field test, 10% even in favour of EVs. Since the expectations of the participants were overall fulfilled it can be assumed that most users do not expect the app to be their only source of information for car purchase. It is rather seen as an aid to analyse certain aspects. Furthermore, many participants favour new vehicle models and the lack of available models is one important point of criticism. This request, however, poses a challenge since the implementation of vehicles requires certain technical data and energy consumption results from ADAC Ecotest for calibration. Further requests were the inclusion of plug-in hybrids and presentation of more differentiated cost information. Besides the energy costs, the additional operational and maintenance costs as well as the depreciation are seen as important. In general, the user wants to compare different vehicles in order to evaluate the economical asset of a car compared to other vehicles. This aspect is not depicted in detail yet but could be implemented in the future to create more transparency in the results.

# 4 Conclusions and Outlook

The "My eDrive" smartphone app and web interface have undergone about one year of field test. Important findings from the user perspective are presented in this paper. Regarding the research questions, it can be concluded that the information which is presented to the user within the app is regarded helpful and meets the expectations of most users. Particularly information about the driving range under user-specific driving conditions is largely appreciated. The approach of a virtual test ride has thus proven reasonable.

The handling of the app was considered easy and intuitive by most users. Technical problems were mostly due to insufficient GPS signal which is mainly due to smartphone-specific issues and has limited implications on the overall system design. It should be noted that the users in the field test generally used newer than market-average hardware. This can be taken as an indication that their technology-affinity is higher – or simply that they have got more money to spend. Both explanations are reasonable for potential early adopters of electric vehicles.

Altogether, the My eDrive concept, comprising energy consumption calculation and user interfaces, has been successfully evaluated during the field test. Furthermore, it has large potential for integration in other areas. Potential application areas for example are

- scientific use of collected vehicle data,
- independent consumer information by public institutions and
- integration in commercial products (navigation, automotive marketing).

The personalized and vehicle specific simulation approach, however, calls for detailed vehicle data. During the development process, these data have been provided by the General German Automobile Club (ADAC). Continuous data availability needs to be ensured for the integration of further vehicle models. In this process also cooperation with vehicle manufacturers or future demands for data transparency on the political side should be discussed.

## Acknowledgments

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[3] Website: www.my-e-drive.de

[4] Website: https://www.zdf.de/dokumentation/planet-e/elektromobilitaet-moeglichkeiten-perspektiven-und-grenzen-100.html

# Authors

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Other key areas include the assessment of the environmental impacts of transport systems.

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