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Insights into Real-World Energy Consumption of Medium-Duty Electric Vehicles

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Abstract

Realistic assessments of the energy consumption of medium-duty battery electric vehicles (BEV) are sparse in literature, but still pivotal for total cost of ownership calculations and ecological considerations. This paper reports on the real-world energy consumption of four types of medium-duty electric vehicles measured in a large German field test. The different energy consumption levels in winter and summer are evaluated. We find that the energy consumption deviates between -8% and 24% from the values provided by the manufacturer and the effect of the season is strongly superimposed by the driving profile.

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1 Introduction

The energy consumption of an battery electric vehicle (BEV) is an important factor influencing the results of total cost of ownership (TCO) calculations, vehicle routing problems, and life cycle assessments [1]. Analyses conducted by [2] concerning deviations between actual, real-world fuel consumption and standardized dynamometer tests – such as the New European Drive Cycle (NEDC) – have raised the issue of unexpectedly high driving emissions and, hence, led to the demand for more realistic data for internal combustion engine vehicles (ICEV). While this discussion has still tangible ramifications for various car producers (Volkswagen, for example), the electric drive has received less attention so far when it comes to real-world energy consumption. This is rather surprising, as this data is not only crucial for calculating the contribution of electrified mobility to climate protection policies, but also for the economic assessment of BEVs. Moreover, uncertainties regarding actual mileage of BEVs are still the major concern when it comes to a key weakness of electric mobility: range anxiety among potential users. As a consequence, individuals as well as companies have to rely on data sheets and driving cycle tests for their purchasing decisions [3].

The goal of this study is, therefore, helping to close this gap with actual, real-world energy consumption of medium-duty EVs using measurements from an extensive field test conducted in Germany. Eventually, differences in energy consumption between summer and winter months, energy consumption increase with a higher stop frequency, vehicle availability and reasons for outages, as well as an assessment of the CO_2-savings due to the BEV opeartion are reported and discussed.

2 Background

We analyze data from the project "Elektromobile Urbane Wirtschaftsverkehre" (acronym: "Elmo"). The German project title translates as "Electrified commercial transport in urban areas"[1]. The project was co-financed by the German Federal Ministry of Transport and Digital Infrastructure and led by the Fraunhofer Institute for Material Flow and Logistics, IML, for the time period between September 2011 and June 2015. In June 2012, the German Federal Government ranked Elmo as a "lighthouse project" for the successful demonstration of electric vehicles in commercial transport [4].

The project conducted one of the largest field tests with medium-duty electric vehicles in Germany. The data in project Elmo were collected in the period from September 2012 to July 2014. During the project's run-time, ten medium-duty electric vehicles of three companies covered over 130,000 km in about two years. All deliveries were carried out in the German federal state of North Rhine-Westphalia. Four different types of BEVs were deployed: three types of up to 7.49 t (7,499 kg or 16,532 lbs) and one of up to 11.99 t (11,999 kg or 26,453 lbs). The BEVs were either utilized for deliveries to third parties (business or end customers) or transport on own account. An overview of the vehicles' specifications and utilization is provided in Table 1, based on information of the vehicle manufacturers within the project and publicly available information, such as data sheets. Due to confidentiality reasons, most of the information provided will be presented in an aggregated form or discussed in comparison to the average values of the German urban freight transportation segment.

Table 1: Overview of the medium-duty electric vehicles utilized in project Elmo

BEV Type	Manufacturer	Transport task	Gross weight [t]	Battery energy [kWh]	Approx. price [€]	Charging time [h]	Range [km]
A	1	Third party delivery	7.49	61	65,000	8-10	80-100
B	1	Third party delivery	7.49	77	75,000	12	105-115
C	2	Third party delivery	7.49	80	110,000	≥ 8	110-160
D	3	On own account	11.99	160	160,000	4.5	200

All utilized vehicles were converted from available diesel models. The BEV type B is an experimental vehicle derived from type A, developed by the same manufacturer. It only differs in terms of battery capacity and weight. Purchase prices are confidential, hence our approximations are based on general information given by the manufacturers. The specific final sale prices depend on the chosen configurations. For the experimental BEV type B we estimated the price based on the information for type A plus the differential average battery costs, which amounted to €437 per kWh in the year 2013 according to [5].

The main focus of the project Elmo was to assess whether battery electric vehicles meet the requirements for day-to-day operations for companies running corporate fleets. One guiding question was how these vehicles can be integrated into existing fleet and logistics operations. As a secondary goal, the project aimed to assess aspects related to traffic, operational processes, energy supply, and ecologic influences which arise during the integration of electric vehicles into the corporate fleet [6]. This paper presents an excerpt and some further evaluations of the data.

The vehicles' data were logged manually by the drivers, since the use of data loggers was technically and legally restricted. Logged data were for example the time, date, duration, distance and number of stops per round trip, as well as the state of charge (SOC) at the beginning and the end of the trip. The data were manually enriched with additional information, such as the average daily temperature in the service area, and the average price of diesel based on the weekly EU oil price bulletin [7]. Qualitative data from interviews (with drivers and operation managers) as well as field studies were used to validate the correctness of the manually recorded data. Moreover, this approach helped to shed some light on vehicle utilization as the data, besides daily round trips, also covered downtime and vehicle outages. Hence, the reasons which impeded continuous vehicle operation during the course of the project can also be analyzed using the Elmo database.

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[1] The final report of the project is available at https://doi.org/10.2314/GBV:867815116 (in German)

3 Results

Throughout the project, the EVs traveled a total of 131,018 km, performed 196,906 delivery stops and consumed 102,736 kWh of energy in total.

Table 2 shows the aggregated mileage and plug-to-wheel energy consumption per BEV type. The latter is compared to the energy consumption given implicitly by the manufacturers by providing the battery size and the range in Table 1.

Table 2: Real-world energy consumption per BEV type in project “Elmo”

BEV Type	Typical route profile	Mileage [km] Recorded average	Mileage [km] Standard deviation	Energy consumption [kWh/km] Manufacturer specification	Energy consumption [kWh/km] Recorded average
A	Urban, 300 stops	73.80	± 5%	0.61 to 0.76	0.74
B	Urban, 300 stops	77.25	± 7%	0.67 to 0.73	0.90
C	Urban, 30 stops	49.04	± 9%	0.75 to 1.09	0.90
D	Freeway and urban, 3-4 stops	92.92	± 12%	0.8	0.73

According to Table 2, the average daily mileage of the two BEV types A and B were relatively similar to each other and constant throughout the months of this study: type A traveled 73.80 ± 5% km (relative standard deviation) per day, type B traveled 77.25 ±7% km per day. Both vehicle types were used to collect and distribute parcel shipments. A typical urban parcel delivery round trip in Germany, suitable for an BEV, is characterized by picking up the parcels in the early morning at a distribution center, then driving a certain distance mostly on urban roads – sometimes also including a short passage on rural roads or freeways – to the delivery area. Here, typically up to 300 stops are performed in order to deliver the parcels throughout the day, with short driving distances in-between the stops in urban traffic conditions. The BEV returns to the distribution center in the evening, where the vehicle is slow-charged overnight. This driving profile is very energy intensive, hence we expected high energy consumptions for these two vehicle types. Indeed, Table 2 shows that the actual energy consumption of the type A vehicles is at the upper margin of the expectations while the experimental type B did not meet the manufacturer’s expectancy and consumed 23% more than maximally anticipated.

The type C BEV transported goods for the companies on own account. The vehicles started from depots located close to the cities’ borders on fixed tours of 49 km ±9%. In the city, about 30 stops were performed, before returning to the depot and slow-charging overnight. The BEV types B and C both have a similar gross weight and nearly similar battery size, but were converted by different companies. Their energy consumptions were nearly at par (although it has to be recognized that type B undertook up to ten times more delivery stops per trip). The type C BEV consumed 0.9 kWh/km on average, in the middle of the range specified by the manufacturer. This result was expectable: on the one hand, energy was conserved, as the cargo was unloaded during the tour, hence the BEV was operated only partly loaded and the drivers were trained by the manufacturer to utilize an energy-conservative drive style. On the other hand, the vehicles were operated in urban traffic, which again raised the energy demand.

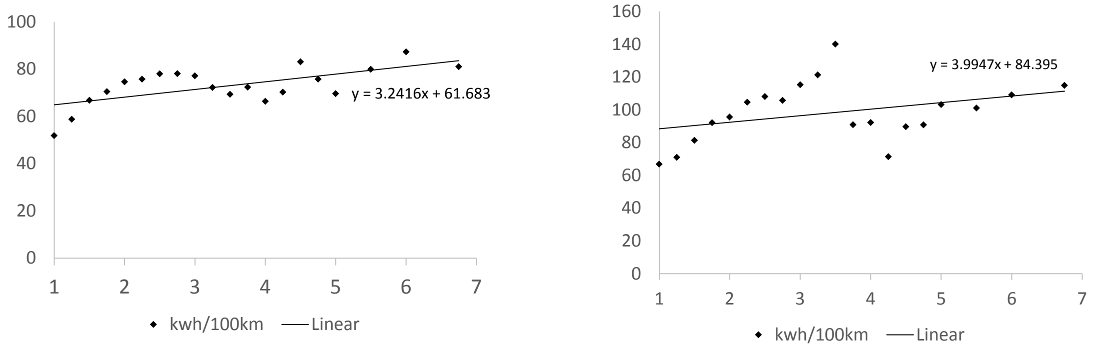
Of all electric vehicles in the field test, type D covered the longest average distance of 94.92 km ± 12% per day. The route profile of this BEV type differed from the others, since it covered longer distances of constant speed between only three to four stops per day. The vehicle received a full slow-charge over night. In order to increase the range, the company tested the partial charging of the BEV when it returned to the depot between the delivery stops by the faster level 2 DC charging. In certain test cases with intermediate charging, the type D traveled substantially more than 300 km per day. With a gross weight of 12 t, type D was the heaviest vehicle in the fleet test and its battery was 160 kWh, which is about double the size of types B and C. The manufacturer reported the BEV range to be 200 km, which translates to an energy consumption of 0.8 kWh/km. Surprisingly, the realistic energy consumption of type D was, with 0.73 kWh/km, 8% below the manufacturers values and had the lowest energy consumption (per kilometer) of all vehicles in the test.

We assume the results are superimposed by other influencing factors, such as different deployment profiles and stop-frequencies; a different use of auxiliaries, such as heating; or different cargo weights in certain delivery seasons, thus these factors are researched in the next sections.

3.1 Energy consumption over stop-frequency

In order to in order to explain the empirically observed differences in the energy consumption of medium-duty electric vehicles and their influencing factors in more detail, we evaluate the energy consumption dependent on the stop-frequency.

In this section, only data of the BEV types A and B are evaluated, since only these vehicles have a relevant stop frequency of up to seven stops per km. The available data was filtered to exclude tour lengths below 30 km. This ensures that only delivery trips are evaluated and test trips around the depot are excluded. Figure 1 shows the energy consumption of both BEV types A and B over the stop-frequency.



(a) Type A (b) Type B

Figure 1: Energy consumption per 100 km over stop frequency per km

Linear regressions between the dependent and independent variables in both figures 1a and 1b depict a trend: with an increasing stop-frequency the energy consumption rises. For the analyzed vehicles energy consumption increases with 3 to 4 kWh/100 km per additional stop/km.

3.2 Variation of the energy consumption throughout the calendar year

The energy consumption of the vehicles is assessed over the calendar year. Figure 2 shows the difference from the average energy consumption for each month per BEV type and marks the largest deviation from the average.

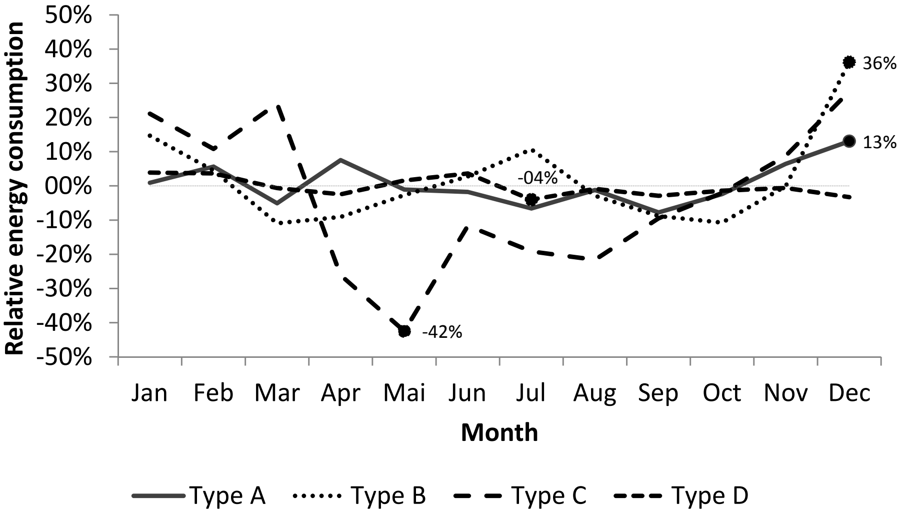


Figure 2: Relative deviation of energy consumption per month from average

Interestingly, the energy consumption differences of the BEV types vary. While type D shows a relative constant energy consumption throughout the year of ±4%, the deviation from the yearly average is especially large for type C (between -42% and +28%).

In order to interpret these results, we compare our results to exemplary findings in the literature: For the 3.5 t parcel delivery vehicles of DHL, an increased energy demand of 30 to 60% was recorded in winter due to an increasing load by auxiliaries [8]. [9] found a 34% increase of the energy consumption in the five "winter" months (November to March) compared to the "summer" (all other months) in a real-world test with 200 electric passenger cars in Denmark. In the area of the Elmo field-test, the average temperature is the lowest (below 10 degrees Celsius) in the same five "winter" months [10]. However, in our real-world test with medium-duty electric vehicles, the "winter" effect is only partly visible. The energy consumption in "winter" increases by 6%, 11%, 32%, and 2% compared to "summer", for the types A, B, C and D, respectively (Figure 3).

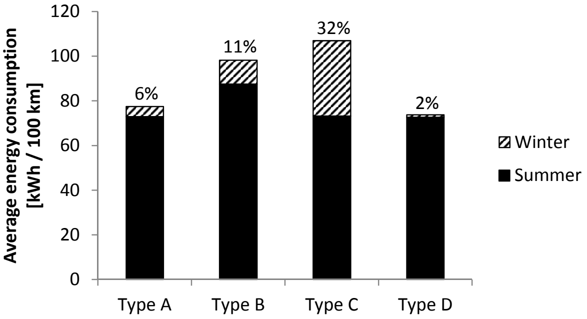


Figure 3: Increase of average BEV energy consumption in winter

Especially for type C, the use of the cabin heating could provide a possible reason for the increased power consumption in winter. It was the only vehicle type in which an electric heating spiral of 2 kW maximum power was actually an option for the driver. BEV type D was equipped with an independent heater (powered by a small combustion engine) so that any influence of the heating on electric power consumption can be ruled out. Furthermore, the auxiliary energy demand is relatively less influential, when the energy consumption from driving increases. This was the case for type D, as the BEV was traveling at higher average speeds with fewer stops and longer stretches of freeway driving. A similar effect has been demonstrated by [11] for passenger vehicles. BEV types A and B also feature a heating spiral of similar maximum power as type C, but drivers were ordered not to use the cabin heating. These vehicles face, furthermore, an increased transport volume and stop frequency towards the end of the year compared to spring or summer. The root causes for an increased power consumptions are, therefore, expected to be rather endogenous than exogenous.

3.3 Reliability of the medium-duty BEVs

Over the project term, the companies recorded per day whether dispatch actually intended to deploy a BEV in the daily operation or not; if so, it was also recorded if the BEVs had actually been used. Ideally, the sum of theses days per vehicle are identical, resulting in 100% availability. As there were outages due to various reasons (cf. below), the general availability of the BEVs was below 100%. Table 3 shows the average availability of each vehicle type throughout the project. The percentages are calculated by dividing the number of days on which a vehicle of a respective type was actually used through the number of days on which the respective company actually planned to use their BEVs.

Table 3: Availability of the medium-duty BEVs on average and per month

Month	Type A	Type B	Type C	Type D
Average availability	82%	75%	61%	58%

The availability of the vehicles is assessed over the calendar year. Figure 4 compares the availability for each month per BEV type and finds that the availability rates are very volatile. A clear trend towards the dependability on the summer or winter season cannot be derived from the data. The available data is further researched in order to better understand the reasons for the outages.

The following categories were used during Elmo to classify all events which impeded planned operations in order to assess the reasons why certain types of BEVs could not operate as expected. When a BEV was intended to be used for delivery, but (due to whatever reasons) was not charged over night precluding it from regular operation, "Battery not fully charged" was written into the vehicle log for the respective day. As some of the vehicles deployed in Elmo experienced recurring breakdowns, some dispatchers excluded BEVs from operation even though they had fully charged batteries and seemed ready for operation.

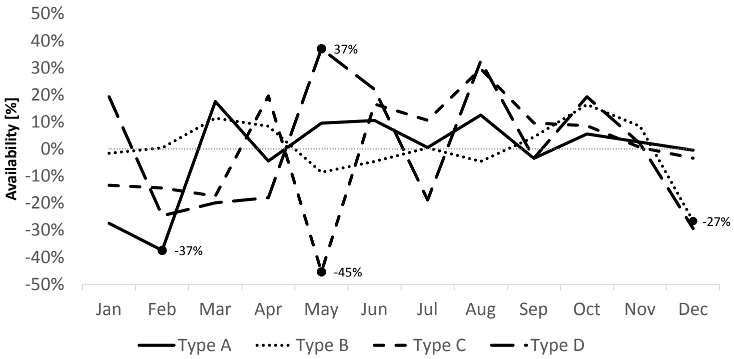


Figure 4: Deviation of the availability of the vehicle types from the average per month

On those days, “Doubts about reliability” was written into the vehicle log. Vehicles which had to be decommissioned because they suffered damage from a crash had “Repairs due to crash” written into their vehicle log for their inoperative days. Likewise, if components not related to the drive train itself had to be repaired (chassis or brakes, e.g.), “Repairs not related to electric drive” was written into the vehicle log for any day spent in the maintenance shop. If a vehicle had to undergo repairs related to the drivetrain, “Repairs related to electric drive” was written into the vehicle log. If local dispatchers generated a route plan for the day which would include routes exceeding typical vehicle ranges, the respective BEV was decommissioned for the day and “Vehicle range not sufficient for route” was written into the vehicle log for the respective day. As stated above, all data had to be recorded manually. Although substantial effort was spent in order to clarify any outage, many vehicle logs recorded ambiguous, unclear, or even no reason to justify why a vehicle had not been used on a regular working day. All these incidents had to be classified as “No reason given”. Table 4 gives an overview on the reasons for the outages per vehicle type.

Table 4: Reasons for outages per vehicle type

	Type A	Type B	Type C	Type D
Battery not fully charged	0%	3%	0%	0%
Doubts about reliability	0%	0%	40%	0%
Repairs due to crash	0%	3%	0%	0%
Repairs not related to electric drive	14%	17%	7%	0%
Repairs related to electric drive	26%	40%	15%	28%
Vehicle range not sufficient for route	48%	23%	0%	0%
No reason given	12%	14%	38%	72%

The numbers clearly reflect that reliability of the charging infrastructure was very high throughout the project. Only once, one type B vehicle experienced the problem of only partially charged batteries. As it turned out, this was not due to a technical defect, but rather caused by someone who pressed the “emergency shutdown” button decoupling the conductive connection between vehicle and charging infrastructure.

General doubts about vehicle reliability were rare and only related to one specific type C vehicle. In fact, it turned out to be so unreliable that it was completely decommissioned during the course of the project because the maintenance personnel involved was not able to locate and solve the technical defects. Repairs due to ordinary road accidents are also a rare event and did not occur more frequently than for combustion powered vehicles.

It is notable that vehicles type A and B reveal substantially more frequent outages due to general repairs not relating to the drive itself. The provenience of the vehicles may offer an explanation for this: both types of vehicles were constructed using the chassis of end of life combustion vehicles. Naturally, these chassis were characterized by substantially more wear and tear (brakes, hinges, etc.) than vehicle types C and D which had been built using brand-new chassis.

Looking at the percentages for drive train repairs, the experimental character of all vehicles deployed in Elmo becomes apparent. Regardless of vehicle type, the drive train itself proved far from being perfectly robust causing a substantial share of the vehicle outages. Especially vehicle type A and B were frequently decommissioned when it became apparent that their maximum range would not meet the operational needs for the day. This is primarily due to the fact that these vehicles had been put on rather short routes compared with the roughly 100 combustion vehicles located at the same distribution center. As the company operating the vehicles experiences seasonal effects leading to increased daily operating times and longer routes, local dispatch decided to rather use combustion vehicles able to meet these demands leaving BEVs in the depot.

3.4 Savings in CO_2-equivalents throughout the test

All electric vehicles were charged with energy from renewable sources, which result in no plug-to-wheel emissions, and well-to-plug CO_2-equivalent emissions of 0.04 kg/kWh; diesel fuel has well-to-tank emissions of 0.57 kg/l and 2.67 kg/l tank-to-wheel [12]. The real-world fuel consumptions of the comparable diesel vehicles in the project are company confidential, hence the overall savings of CO_2-equivalents in the test may only be estimated: assuming the consumption of the conventional fleet between 0.2 and 0.25 l/km, the ten vehicles saved 81 to 102 t of CO_2-equivalents throughout the test. Naturally, this potential increases by up to 1.5% (i.e. zero well-to-plug emissions) when the respective vehicle owner makes use of local sources of renewable energy. In case of BEV type D, over the course of the project time frame, on average 29% of the electricity required to charge the vehicles came from a large photo-voltaic array mounted on the roof of the distribution center. With respect to the confidentiality of fuel consumption data, we are able to report the following range of possible savings in CO_2-equivalents: BEV types A to C: 20 to 30 kg/day, BEV type D: 90-100 kg/day. The substantial differences trace back to two different aspects: i) different average daily mileage: BEV type D served up to two or three routes/day while A to C only had one; ii) higher fuel savings per km: BEV type D replaced a heavier truck with a substantially higher fuel consumption per km than the conventional vehicles' replaced by BEV types A to C.

4 Discussion

It can be observed that the BEV manufacturers communicated an expected range of an BEV, instead of a fixed energy consumption according to a standard measurement procedure, i.e., DIN 70030-2. One of the manufacturers reasoned that the BEV range and hence energy consumption depends largely on the ambient temperature, drive style, topography, number of stops, usage of auxiliary loads, etc. Hence, the manufacturers were hesitant to provide a misleading measurement value and rather indicated an expected range according to the intended customer's use case.

The energy consumption deviated between -8% and 24% from the values given by the BEV manufacturers. In the real-world tests of [1] and [9], the electric passenger car energy consumption is reported to be between 29% and 64% higher than stated in the data sheets according to the NEDC measurement. Hence, the freight BEV manufacturers' information on the expected range and thus energy consumption gives a better estimation of the realistic consumption than the available information for passenger vehicles, which is usually based on NEDC measurements.

The heaviest vehicle (type D) had the lowest energy consumption in the field test. All vehicle types were deployed in the same federal state, with a roughly comparable climate, topography and payload profile. Assuming that all vehicle types were driven by trained drivers applying an energy-conservative driving-style and at least for types A, B and D had a similar usage of auxiliaries, the main difference between the usage profiles was that type D undertook less stops and the tours contained longer stretches of freeway driving. The increased energy demand of 3-4 kWh/100 km per additional stop per km of the BEVs of type A and B supports the suggestion, that medium-duty BEV energy demand increases with the number of delivery stops in urban traffic and reduces in more smooth traffic conditions, similar to conventional diesel vehicles. Whether the effect is attenuated compared to diesel vehicles, due to the recuperation of energy when braking, has not been assessed in this study.

However, while average energy consumption given by the manufacturers seems to deliver a relatively good estimate, our data supports the hypothesis that the higher energy consumption in winter season can be a limiting factor for BEVs. Especially, coupled with a potential higher stop-frequency due to the Christmas delivery peak, these factors together can lead to a significantly reduced reach of the medium-duty BEVs, and hence a lower acceptance rate of the vehicles.

Equipping a BEV with a larger battery might not automatically lead to a higher range, as the evaluation of the energy consumption of the BEV types A and B suggests. Both BEVs are identically constructed and equipped with a similar battery type, only battery size differs. Further, both electric vehicles are deployed by the same company, on similar route profiles and climate conditions, with comparable cargo loads. Assuming a comparable use of auxiliaries, the additional energy consumption of the BEV type

B (0.90 vs. 0.74 kWh/km) suggests that the larger and thus heavier battery potentially had a negative impact on the range gain. Deriving the range from the realistic energy consumption shows that vehicle type B can only travel about 3 km more than type A, while costing approximately €10,000 more, due to the larger battery. Hence a larger battery might not automatically lead to a higher range, since the vehicle's gross weight and hence the energy consumption increases.

5 Conclusion

This section summarizes the contribution of our approach, reports on the limitations of the data and our approach and suggests further research based on our insights.

In this paper, we provided insights of real-world energy consumption of medium-duty electric trucks deployed in an urban environment. The numbers reported stem from a field test in Germany and, therefore, must be assessed with the background information of the respective use case which we also outlined here. As a first result, we are able to give an indication of actual ranges and maximum route lengths for 7.49 t and 12 t trucks and quantify seasonal influence (i.e. ambient temperatures). Moreover, using the data from vehicle types A and B, we found some initial evidence for our hypothesis that the energy consumption per kilometer increases with an increasing number of delivery stops per kilometer.

Providing insights into real-world energy consumption can only regarded as a first step, especially because the principles of data capture in Elmo relied on manual recordings, i.e. vehicle and charging logs. The information collected relates only to complete routes and charging processes. As we recorded the energy consumption from the charging infrastructure side, our figures include the small but existing electrical losses incurred during charging. This means, that the actual consumption figures have to corrected if our numbers would be used to derive actual vehicle ranges from battery capacities. Moreover, the route profile (types of roads used, average velocities per road type, individual delivery stops, etc.) has not been recorded in detail. This is particularly important when assessing the density of stops per kilometer and mileage. Finally, temperature information has not been collected from vehicle mounted sensors, but from public sources located in the respective service region.

From a methodological point of view, future research should rely on automated logging instead of manual data capture. However, experience from Elmo shows that keeping aggregated (for example, weekly) logs is helpful to validate the recorded trips and throughput of energy to charge the vehicles. Moreover, it forces drivers and managers to continuously report issues and information which cannot be tracked by logging devices, especially reasoning behind certain driver decisions, like reactions to vehicle behavior, encountered traffic incidents, or even break downs. The operational use of BEVs should be continuously monitored and tracked in order to capture all processes charging and draining the battery along with the relevant logistical parameters characterizing payload, mileage, operating time etc. All this information has to be used to create refined models for BEV-related route planning and scheduling. Using the data from Elmo, [13] illustrate how interim charging may lead to a profitable vehicle operation for the case of BEV type D. Especially when interim charging is an option, detailed information on actual energy consumption will become particularly relevant for vehicle manufacturers as interim charging allows to create vehicles with smaller batteries and increased payload. In order to gain fruitful insights into the actual usefulness of BEVs for logistical applications, it is, moreover, not enough only to track the electric vehicles in all detail. Likewise, comparable combustion-powered vehicles should be tracked in order to generate suitable benchmark data. As we described in one of our first paragraphs of this paper, fuel-consumption of combustion-powered vehicles is also a parameter which requires more reliable data. For the purpose of benchmarking BEVs, to calculate actual TCO differences, possible monetary savings, and ecological benefits, this data is also desperately needed. Based on the insights gained from Elmo, researchers from Fraunhofer IML have already initiated a follow-up project ("EN-WIN"[2]) which focuses on medium-duty BEVs (7.49 t up to 26 t). In this project, data capture will be processed through logging devices on-board of BEV and comparable combustion vehicles in order to track real-world power consumption for both types of vehicles using a detailed time grid which allows analyzing the influence of payload, temperature, velocity, kilometers driven etc. [3]

We derive the following implications for the business model of vehicle manufacturers. While the vehicle range is a non-issue for current diesel trucks and, hence, is not addressed by vehicle manufacturers. Yet, in order to mitigate planning and operational risks for vehicle operators, it becomes pivotal for manufacturers not only to provide reliable range data for their vehicles, but also to get more involved in the vehicle deployment process. The process of selling trucks will, therefore, change when it comes to electrified transportation because a substantial analysis of the actual transport requirements has to take place in order to assess whether a certain vehicle is actually able to operate under specific conditions and on

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[2] This project is co-funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

[3] http://www.en-win.de (in German)

certain routes. This does not only relate to vehicle range, but also to the time slots available for charging and, finally, also to the local electrical infrastructure. A BEV manufacturer, therefore, will have to offer a bundle of services centered around the electrical vehicle in order to provide the required preconditions of electrified transport (most importantly, infrastructure, improved planning procedures for dispatch, and training for operational staff). In order to ensure customer satisfaction with electric trucks, it can also be expected that manufactures will include instant vehicle replacement in case of breakdowns as well as guaranteed aftermarket prices for used trucks. How to design and produce this service portfolio, however, will be subject to strategic business decisions to be taken by the manufacturers. But as vehicle range and reliability, suitability for operation, and possible business cases are pivotal for the logistics companies, these might expect opportunistic behavior by vehicle makers. As a consequence, the expanding market for electric trucks will also create a market for a neutral and objective assessment of realistic BEV performance and requirements.

References

[1] C. De Cauwer, M. Maarten, S. Heyvaert, T. Coosemans, and J. Van Mierlo. Electric vehicle use and energy consumption based on real-world electric vehicle fleet trip and charge data and its impact on existing EV research models. In *28th International Electric Vehicle Symposium, May 2015, Korea*, 2015.

[2] Uwe Tietge, Sonsoles Diaz, Peter Mock, John German, Anup Bandivadekar, and Norbert Ligterink (TNO). From Laboratory to Road. A 2016 update of official and real-world fuel concumption and CO_2 values for passenger cars in Europe. Whitepaper. Technical report, The International Council on Clean Transport (ICCT), Netherlands Organisation for Applied Scientific Research (TNO), 2016.

[3] Philippe Lebeau, Cathy Macharis, Joeri Von Mierlo, and Kenneth Lebeau. Electrifying light commercial vehicles for city logistics? A total cost of ownership analysis. *European Journal of Transportation and Infrastructure Research*, 15:551–569, 2015.

[4] BMWI. Leuchtturmprojekte der Elektromobilität, 2012. Last accessed January 20, 2016.

[5] B. Nykvist and M. Nilsson. Rapidly falling costs of battery packs for electric vehicles. *Nature Climate Change*, 5:329–332, 2015.

[6] S. Stütz, A. Bernsmann, T. Baltzer, N. Hentschel, K. Pommerenke, B. Rogmann, and P. Wunderlin. ELMO – Elektromobile Urbane Wirtschaftsverkehre, Projektabschlussbericht. Dortmund, 2016.

[7] European Commission. Weekly oil price bulletin. Last accessed February 10, 2016.

[8] Tessa T. Taefi, Jochen Kreutzfeldt, Tobias Held, Rob Konings, Richard Kotter, Sara Lilley, Hanna Baster, Nadia Green, Michael Stie Laugesen, Stefan Jacobsson, Martin Borgqvist, and Camilla Nyquist. Comparative analysis of European examples of freight electric vehicles schemes. In Herbert Kotzab, Jrgen Pannek, and Klaus-Dieter Thoben, editors, *Dynamics in Logistics*, pages 495–504. Springer, 2016.

[9] Gebeyehu M. Fetene, Carlo G. Prato, Sigal Kaplan, Stefan L. Mabit, and Anders F. Jensen. Harnessing big-data for estimating the energy consumption and driving range of electric vehicles. In *Final manuscript for presentation at the 95th Annual Meeting of the Transportation Research Board*, Washington D.C., 2016.

[10] Wetterdienst. Klima Dortmund – Station Waltrop-Abdinghof (68 m), January 2016. Last accessed February 1, 2016.

[11] Maximilian Schücking, Patrick Jochem, Wolf Fichtner, Olaf Wollersheim, and Kevin Stella. Influencing factors on specific energy consumption of ev in extensive operations. In *29th International Electric Vehicle Symposium, Montreal, Canada*, 2016.

[12] Umweltbundesamt. Handbuch für Emissionsfaktoren des Strassenverkehrs 3.2 (HBEFA), 2014.

[13] Maximilian Schiffer, Sebastian Stütz, and Grit Walther. Are ecvs breaking even? competitiveness of electric commercial vehicles in medium-duty logistics networks, 2016. Accessed June 19, 2017.

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