Task force 41
Electric Freight Vehicles

The State of the Art of Electric Freight Vehicles
Technical Performance

The main challenges in the technical performance of Electric Freight Vehicles (EFV) are the available range, payload and charging time today. The traction battery has a major influence on the indicators. In addition, the limited availability of EFV models and the rapid technological development plays a major role in the attractiveness of EFV in the market [1]. However, the market is developing rapidly. The question therefore arises whether the current state of performance of EFV is competitive with a conventional freight vehicle today.

Benchmarking Electric Freight Vehicles

A benchmark analysis of EFV was carried out using technical information on all available vehicle models and concepts that are publicly known. This includes Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV), Range Extended Electric Vehicles (REEV), Fuel Cell Electric Vehicles (FCEV) and Battery Electric Vehicles (BEV). The collected information was compiled over a time period from April 2018 to April 2020 and has been consolidated in a vehicle database. The data contains the standard specifications of the vehicles with technical data such as power, battery capacity, range etc.

From the research, 265 vehicles were collected. These are divided into 108 light-duty vehicles (N1 category, under 3.5t GVW), 65 medium-duty vehicles (N2 category, 3.5 - 12t GVW) and 92 heavy-duty vehicles (N3 category, 12 - 40t GVW) – see Figure 1. In the light segment, almost every second vehicle registered is also available in series production, and if e-converted vehicles are included, this applies to almost 70% of the light-duty vehicles. Therefore a high degree of production readiness has already been achieved in the light-duty segment. In the N2 category are fewer series vehicles and more vehicle concepts available than in the N1 category. The start of series production of these vehicles is announced by the manufacturers for mid-2020 and 2021 [2–4]. More vehicle concepts are known in the N3 category than in the N2 category. These are mainly new market players with concepts and prototypes. In principle, a lower production readiness level can be identified with increasing gross vehicle weight. This is mainly due to the technical requirements for heavy-duty vehicles in long haul transport that cover longer distances and have more demanding payload profiles.

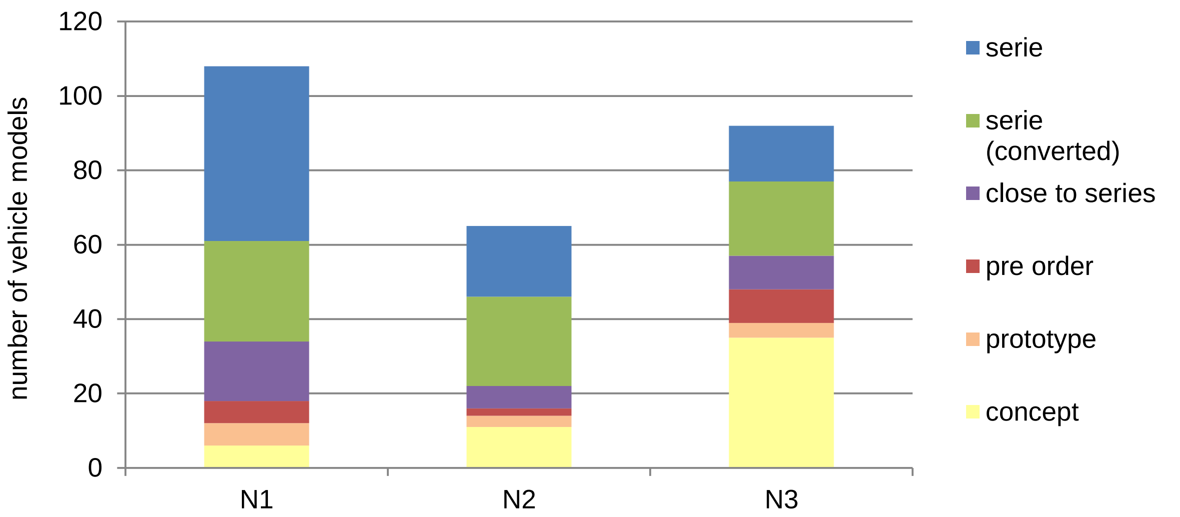

Figure 1: Production readiness of EFV by vehicle category

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Range and Payload of EFV

On average, the range of the battery-electric vans available on the market is 150 km. The ranges go from 64 km to 500 km – see Figure 2. In the upper section, REEV is more likely to be found than BEV. The manufacture VW promises a range of 173 km according to NEDC for the Model e-Crafter (BEV). After WLTP the value is even lower as first tests shows that for the VW e-Crafter 120 km seem to be more realistic [5]. The diesel version of the VW Crafter has a range of about 1000 km. Based on the typical daily tour profile of a delivery vehicle in urban area, a range of 100 to 150 km is probably sufficient [1]. However, the limiting factor depends strongly on logistic operations, such as payload, and external conditions such as temperatures, driving style and traffic [1, 6].

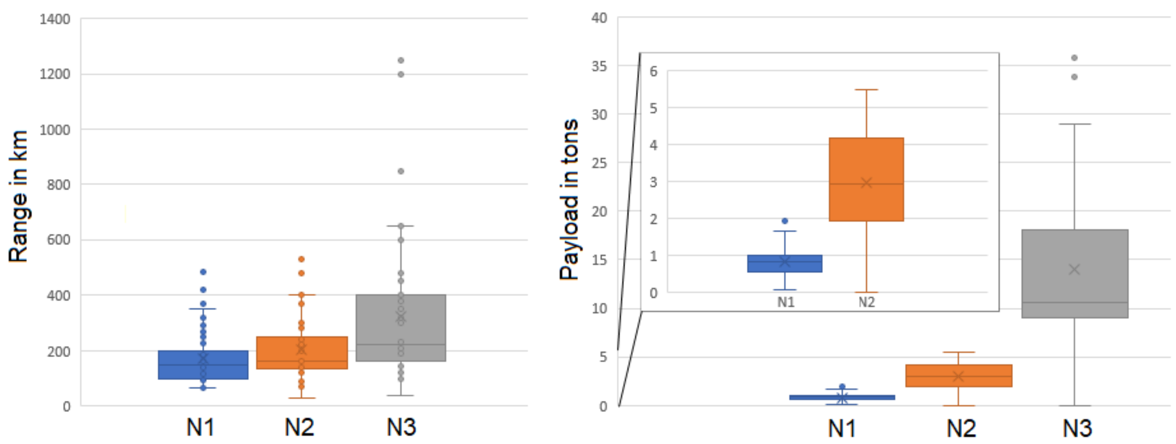

Figure 2: range and payload of EFV

The increase of the electric range and thus the battery capacity goes hand in hand with an increase in the mass of the traction battery, which is in conflict with the available vehicle payload in the corresponding vehicle segment. This optimization problem is one of the challenges for the design of EFVs but has improved in recent years with developments in battery efficiency. The vehicle payload of electric vans ranges from 200 kg to 1,950 kg with 835 kg on average (see Figure 2). Regarding the driving range of N2 category vehicles, the current performance varies from 30 km to 530 km with an average of 160 km. Vehicle payload ranges from 1,000 kg to 5,500 kg with 3,100 kg on average. For the N3 category vehicles, the driving range varies between 40 km to 1250 km with 220 km on average. Vehicle payload ranges from 4,400 kg to 36,000 kg with 11,100 kg on average.

Charging time of EFV

Whether the range is a limiting factor for vehicle operation also depends on the availability of the charging points and the charging speed [7]. Charging time varies largely depending on the type of electric vehicle supply equipment and type of battery in the vehicle. Alternating Current (AC) and Direct Current (DC) charging systems are available. With the AC system, regular charging is possible via the household power grid (e.g. via wall-box). DC charging has the problem that the batteries in the vehicle can quickly become overheated. Most EFV are driven by an AC motor. In the mentioned database, 72% of the listed EFV have synchronous motors, most of them as permanent magnet synchronous motors due to their high efficiency. The remaining 28% have an asynchronous motor. An example of series battery-electric freight vehicles with information about the battery capacity and the charging time according to AC and DC is shown in Table 1.

Table 1: Battery capacity and charging time of series battery-electric freight vehicles

Vehicle Class	Vehicle model	Battery capacity [kWh]	Charging time AC 0-100% [h]	Charging time DC 0-80% [min]	Max. range [km] (without payload)
N1	Nissan E-NV200 (3,5 t.)	40	5,5 (11 kW)	40 (50kW)	275 (NEFZ)
	Mercedes eVIto (3,5 t.)	41,4	10 (11 kW)	80 (50kW)	150 (WLTP)
N2	IVECO Daily Electric 50C (7,5 t.)	80	4,2 (22 kW)	40 (50 kW)	280 (NEFZ)
	FUSO eCanter (7,5 t.)	82,8	12 (22 kW)	105 (50 kW)	100 (WLTP)
N3	Volvo FL Electric (16 t.)	300	13 (22 kW)	60-120 (150 kW)	300 (NEFZ)
	Volvo FE Electric (27 t.)	300	10 (22 kW)	90 (150 kW)	200 (NEFZ)

Depot charging is most attractive for freight transport because it offers a high degree of flexibility in operation. For depot charging, fleet operators usually need their own charging points at the depot. The vehicles are then preferably charged overnight or during the day (opportunity charging), as in some transport task vehicles has to return to the depot during the day. For the heavy duty vehicle segment 150-kW DC-charger is appropriate but a minimal standard. For the most sub-contractors or similar logisticians who do not have a private parking space for their vehicles it is more difficult to find suitable charging business cases. Their vehicles are usually parked overnight on public roads. For electric vans there is the possibility to charge them via the current public charging infrastructure. For this purpose common 50-kW DC-Chargers (standard CCS) are suitable.

Logisticians often complain about the long charging time of EFV. However, 90 percent of today's vans are parked overnight at a fixed depot [1]. Considering the average charging time via a 11kW/22kW AC-charger (see Table 1), electric vans could be conveniently recharged overnight. Public 50kW/150kW DC-Charger could be additionaly used to recharge the vans between the daily tours. As mentioned, public charging is seen more as a supporting factor in the charging strategy of EFVs, and will not be able to replace the own charging station with fixed parking space in the depot [1]. However, the relatively long charging time compared to conventional diesel refuelling can be regarded as no problem in some applications already today.

Battery technology of EFV

The way and frequency of charging and discharging determine the battery life. The charging time of the battery depends on the limited electrical intensity to avoid irreversible damage to the battery [7]. A health indicator of batteries is the capacity. Lithium-Ion (Li-Ion) batteries loses on average more than 20% of their capacity over lifetime [7]. For Li-Ion batteries in electric vehicle the lowest capacity loss is reached by charging the Li-Ion battery (at 20°C) between 25-75 percent state of charge (SOC). This would delivery around 3,000 cycles (to 90% capacity) [8]. In real operation these operational parameters (charging strategy (speed), depth of discharge, operating temperatures, tour profile etc.) vary strongly and make it therefore harder to estimate the average lifetime of the battery.

Most electric freight vehicle are using Li-Ion batteries. Furthermore, LiFePO4 is the most common cathode material in the Li-Batteries. Compared to the passenger car market, few vehicles with Li-NMC batteries are known in the commercial vehicle market. In addition, there are many vans (mostly older models) that are operated with a lead-acid battery. However, lead-acid batteries have a lower energy density and shorter lifetime than Li-Ion batteries. Figure 3 shows the known battery technologies of the battery-electric freight vehicle according to the vehicle categories.

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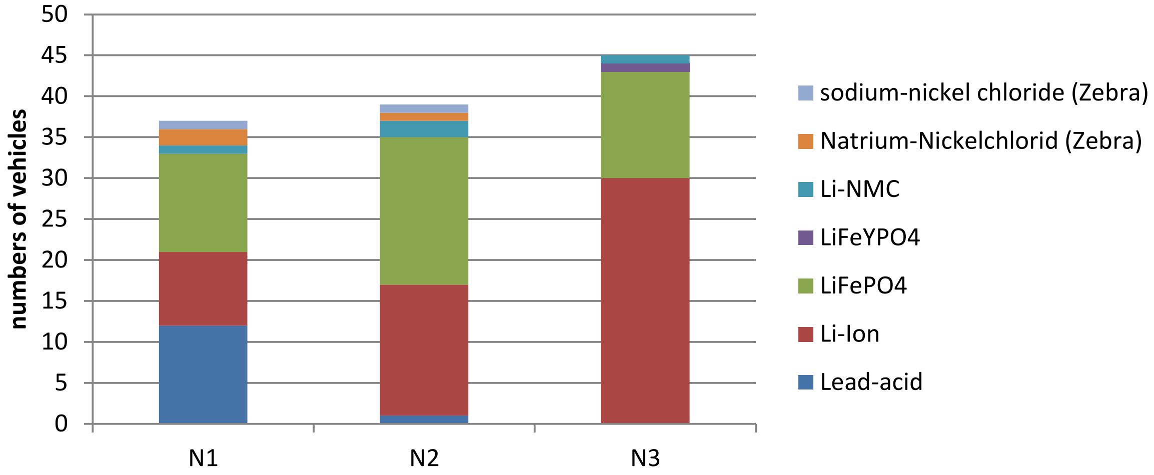

Figure 3: Battery technologies of EFV

EFVs available on the market today demonstrate important technological progress in comparison to vehicles from 10 to 20 years ago. The technical indicators show that some EFV are potentially as efficient as conventional vehicles. With the rapid development in battery technology, further technological improvements in terms of range and payload of freight vehicles can still be expected.

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