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Suitability of Commercial Transport for a Shift to Electric Mobility with Denmark and Germany as use cases

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Abstract

This paper identifies commercial sectors suitable for a shift to electric mobility in Denmark and Germany. Furthermore, policies to promote the use of electric vehicles are discussed. The paper concludes that the Construction, Health care service and Other service sectors are most suitable ones for electric mobility because many vehicles are registered in these sectors and daily mileage is reasonably low. They should be primary target groups of specific policy measures to promote the use of electric vehicles, e.g. information campaigns, company support to analyse feasibility of EVs and changes in regulations.

Both Denmark and Germany have incentives to promote the use of electric vehicles. Nevertheless, electric vehicles do not show economic benefits unless travel distance is high. However, today the travel range of large vans is an important barrier for electrification due to the battery weight and the limitation of 3.5 tons gross vehicle weight for driving with a normal driving license. The rule needs amendments for electric vehicles as has been done in Germany. The paper recommends EU countries to follow the German rule allowing EVs up to 4.25 tons to be driven with a licence class B and thereby create a market for big vans with long travel range.

Key words: commercial transport, electric mobility, light duty vehicles, policy incentives, driving license regulation

1 Introduction

To promote the application of a more sustainable and cleaner freight transport the use of electric vehicles (EVs) may be an attractive solution to improve air quality in the city centre, reduce CO2emissions, and reduce noise nuisance (Van Duin et al., 2013; Kemp et al., 2000). Until now, mainly private electric passenger cars have been studied. However, in recent years the use EVs has begun to spread to other transport sectors as well. Indeed, global retail and delivery companies have started to consider using alternatively propelled vehicles. Although so far, the consideration concerns only a marginal share of the fleet (Bae et al., 2011). In recent years, several research projects have been carried out regarding user needs (Hoogma, 2002; Evans and Azmin-Fouladi, 2005; COMPETT Team 2015), user acceptance (Green eMotion Team, 2015; Globisch et al. 2013; Kasten et al. , 2011; Kreiner et al., 2011) and identification of mobility patterns in relation to electric vehicles (Hackbarth et al., 2010; Reiner et al., 2010; Bühler et al., 2011; Franke et al., 2012; Schuller and Hoeffer, 2014; Hanke et al., 2014; Scott et al., 2014). Most of these projects focus on private users and electric passenger cars. Especially due to the lack of electrified light duty vehicles little is known regarding the use of electric vehicles for commercial transport, i.e. transport of goods and service delivery vehicles. But research into the potentials for passenger EVs in commercial applications is widely neglected, too.

Several requirements need to be fulfilled for a company to replace their conventional cars with EVs. Firstly, the transport requirements and expectations expressed by drivers and/or operators have to be met. This is clearly demonstrated by the evaluation of the Swedish electric vehicle procurement trial for commercial fleets in 2010-12 (Wikström, 2015; Wikström et al., 2015, 2014).The study is the most comprehensive study in Europe known to the authors focusing on commercial use of EVs. . Secondly, the EV has to be economically feasible or even more attractive than a conventional vehicle (Bae et al., 2011; COWI, 2014; Feng and Figliozzi, 2013). Thirdly, the vehicle needs to be accepted by the owner and/or the vehicle manager (Kaplan et al., 2015).

1.1 Policy to support development in the commercial EV market

In Denmark EVs have been exempted from purchase tax and annual user tax from 2009 to 2015. This exemption will be phased out from 2016 and disappear from 2020 (Skatteministeriet, 2015). As only passenger cars and small vans pay purchase tax the tax exemption have mainly had an effect on the price of passenger cars. Furthermore, power suppliers selling electricity to companies can do this for free when it is dedicated to mobility. During 2008 to 2015, the Danish government has set up different EV programmes to support the introduction of EVs and the development of a charging infrastructure with an overall budget of €12 million (Energistyrelsen, 2015). The programme has resulted in an increasing network of fast charging stations and local low power chargers. Companies could also exploit this initiative. Free parking in city centres has been local initiatives. This possibility is now included in Danish legislation, but in a reduced version in which the reduction of the parking fee cannot exceed the value of the environmental benefit of the EV. In Denmark no economic initiatives dedicated to commercial EVs have been taken.

In Germany the promotion of electric vehicles was implemented in the plan of four German ministries to develop Germany as lead market for electric mobility (BMBF 2008). A goal of one million electric vehicles by 2020 was set in 2009 (Die Bundesregierung, 2009). One of the first main projects was the funding of eight model regions. More than 150 projects in technology and demonstration of vehicle deployment were supported with very scattered financial aids. The governmental support programme was continued in 2011 with R+D in six regional show cases (Dudenhöffer et al., 2012). Since 2011 electric vehicles and plug-in hybrids have been exempted from the annual vehicle tax for five years whereas no policy measures reduce the purchase price.

Further measures have been introduced to enhance the market penetration of EVs. E.g. the Electric Mobility Promotion Act was ratified in 2014. It allows the federal states of Germany to grant EVs priority over other users when, for example, parking in public spaces or using bus lanes (Deutscher

Bundestag, 2014; Trommer et al., 2015). A special focus is applied to commercial vehicles, because a substantial market growth can be reached in commercial fleets with relatively modest financial support (Gnann et al., 2014). The German government plans more subsidies to expand the charging infrastructure for EVs, especially more public fast charging stations shall be installed, and further public funding for research and development of electric mobility. Furthermore, the federal government is considering a special depreciation for zero-emission company cars.

Even though a growing number of EVs are observed in recent years, numbers are far from the ambitious 2008 goal. Only 8,500 BEVs (battery electric vehicles) and 4,500 PHEV (plug-in hybrid electric vehicles) were newly registered in Germany in 2014. At the beginning of 2015 only 18,948 BEVs were registered. A similar situation is found in Denmark. In spite of the massive public support only around 4,000 EVs are on the streets by the end of 2015 (Dansk Elbil Alliance, 2015).

The number of EVs per capita is smaller than in e.g. Sweden (10,000 of which commercial vehicles represent a substantial share (Wikström, 2015)) and especially smaller than in Norway (50,000 (Figenbaum et al., 2014)). The success of the EVs in Norway is due to both substantial economic incentives (tax and VAT exemption, free parking, no charge in the toll rings) and a number of initiatives favouring EVs such as use of bus lanes. (Figenbaum et al., 2014). No policy issues are however dedicated to commercial vehicles. (Holtsmark and Skonhoft, 2014) are furthermore questioning the economic feasibility of the unusually high economic support.

1.2 The purpose of the paper

Compared to private mobility the transport needs of the commercial transport sector are much more diverse. Usage patterns are subject to customer requirements, financial and organisational conditions or restrictions (HEBES et al. 2010). However, there is no general pattern; rather each economic sector and sub-sector may have its own particular way of organising its mobility. Nevertheless, transport surveys show that driving patterns in some business branches are more suitable for the application of EVs than others. Thus target group specific policies for the promotion of electric mobility might be attractive. Christensen (2011) for instance shows that for Denmark around 80% of vans and 70% of small lorries drive less than 150 km per working day. Some sectors have highly identical uses of their vehicles over a long period, which is e.g. the case within the Swedish procurement programme (Wikström et al., 2015), whereas in other sectors the daily driven distance may vary strongly from day to day, e.g. in the service sector.

A detailed picture of the variety of potential users and their requirements is necessary to assess the market potential for EVs and to develop adequate political instruments to facilitate the introduction of EVs. In this light, recent policy measures (mainly R+D programs) to stimulate commercial purchases of EVs need to be evaluated. These programmes are usually designed for a general promotion of EVs. In this paper we analyse different business sectors in detail to enable politicians and municipalities to design stimulus programmes targeting specific groups, which are most suitable for EVs at the current state of technological development. The results are also valuable for the automotive industry for it to know for which business sectors EVs should be designed.

This paper presents the results of statistical analyses of the commercial transport sector in Denmark and Germany enriched with more detailed analyses based on GPS tracks. The analyses show to which extent vehicles in the different economic sectors have a driving pattern making it possible to replace the existing conventional vehicles with electric vehicles. Furthermore, for both countries we determine the economic sectors with the highest potentials.

2 Methodology

2.1 Assessment of the potential for EVs per economic sector

In order to assess the potential for EVs of each economic sector three analyses were conducted for Germany and Denmark:

Firstly, an overview of the size of the commercial vehicle stock distributed on sectors is presented. Thus, we will be able to identify economic sectors representing a high number of vehicles. The following sections will mainly focus on these sectors.

Next, the distribution of the average travel distances and trip lengths are analysed for passenger cars, vans and light duty vehicles (LDV) with a gross vehicle weight (GVW) up to 12 tons for all economic sectors according to the statistical classification of economic activities in the European Community (NACE, see European Commission, 2015). Only these three vehicle segments are analysed as there are nearly no electrified trucks available on the market. The objective is to uncover the variation in travel distance of vehicles of different sizes and sectors and discuss these in relation to the possible range of commercial EVs. The daily travel distance is important to assess if the vehicles can drive a full working day without being charged whereas the stop length shows if it might be possible to charge during the day. In this way it is possible to assess the share of the stock in each sector which technically will be suitable for a change from conventional to electric vehicles dependent on the travel range.

Finally, we analyse the daily variation in mileage of the vehicles in some companies of the most promising economic sectors by GPS-logging to proof the robustness of the results and the applicability of EVs. In daily life it is necessary for the EV owner to be able to drive every day without using time on charging unless it can be done simultaneously with other duties. An average travel distance per day calculated over one or more years does not show how many days the permissible mileage of the EV would be exceeded and therefore it is necessary to assess the daily driving pattern.

In the discussion section the main contribution will be on policy problems related to a substantial introduction of commercial EVs.

2.2 Criteria: maximum driving range

As described above a limiting criterion of EVs is the maximum daily mileage for vehicles. The maximum driving range of most of the passenger EVs presently at the market varies between 130 and 200 km according to the manufacturers. An exception is the luxury and expensive passenger cars from Tesla Motors with a maximum range up to 500 km. The average maximum mileage of LDVs according to the manufacturers varies between 100 and 170 km.

In practise the travel range is however not as long as promised by the test driving circles, according to e.g. results from the Danish support programme financed by the Energy Department (Energistyrelsen, 2015). The travel range depends on the individual driving behaviour related to speed, acceleration and breaking (Duke et al., 2009; Energistyrelsen, 2015; Fetene et al., 2015; Greaves et al., 2014). Furthermore the driving range is reduced due to outdoor temperature (use of heating, air condition etc.) (Fetene et al., 2015), topography of the area and transported weight (number of passengers, weight of goods etc., size of car). By using the energy consumption model developed in (Fetene et al., 2015) on GPS tracking of conventional vehicles, both passenger cars and vans, driving during summer and winter periods the mean driving range is derived in a Danish environment (the reference is removed due to double blind review). The resulting mean driving range is 158 km during a summer period and 115 km during a winter period for passenger cars like Nissan Leaf, E-Golf and Mercedes B which have an official driving range of 200 km. For the Nissan e-NV200 van, with an official range of 170 km when fully charged, the travel range in real traffic during a summer period is only 111 km. For all cars it is assumed that the drivers drive the car in the same way as they drive a conventional car.

Range anxiety has to be considered too. (Wikström et al., 2014) show that employees who can choose between electric and conventional vehicles from a fleet with both kinds of vehicles generally choose a conventional vehicle if the expected distance to drive during the specific day might be longer than approximately 70 km. When a vehicle is assigned to only one user, the user tends to choose a conventional car in case a proper introduction on how to use EVs was not given initially. Especially in these situations, a daily mileage up to 100 km stresses the users. In Swedish winter periods the EVs are used rather little and the use is not higher during the second year of the trial indicating that fleet drivers who have a choice do not get more confident with the travel range and avoid the EVs in cold weather. (Sun et al., 2014) show based on studies of mid trip charging by Japanese EV drivers that a commercial EV during a working day will require 3.6-5.2 kWh as a minimum power left when charging. The level probably depends on branch and type of trip but the explanation is not further uncovered. With a 24 kWh battery this equals 15-20 % of the capacity, which under average conditions reduces the above mentioned travel ranges to 125-135 km for a passenger cars in a summer period and 92-98 km during the winter. For the LDV with the lower official travel range the practical travel range will only be 88-94 km in a summer period.

Recharging during the day will extend the daily travel range. However, recharging takes several hours. When considering loss in the converter a normal electric outlet allowing 10 Amp only delivers 2.1 kWh per hour (Christensen, 2011). Using fast charging a substantial recharge can be performed within 20 to 30 min. (up to 80% of the battery capacity), but fast charging facilities are scarce and normally not available where commercial vehicles need them. (Wikström et al., 2015) therefore show that recharging is only very seldom applied by commercial EV users.

As an outset for the analyses two thresholds are applied:

- 50 km maximum driving range without recharging: Vehicles driving less than 50 km per day is assessed to be suitable for electric mobility in any case.
- 100 km maximum driving range without recharging: Most of the passenger cars are able to drive up to 100 km even though they, with the actual technology, need to adapt their driving pattern in winter time. For LDVs this travel range can only be overcome when considering next generations of electric LDVs.

2.3 Data

The analysis of commercial transport in Denmark is based on two datasets maintained by Statistics Denmark, the annual version of the Danish Central Vehicle Register with detailed information about the vehicles including type, total net weight, and ownership and a dataset with the results of odometer readings at the mandatory inspection of the vehicles in the period 2007-12 (called SynsData). All data analyses are completed at a closed computer environment at Statistics Denmark with access to the full databases. The average daily mileage is calculated from SynsData. The calculated mileage from before 2006 and from periods where the ownership was changed between the two readings is removed. The odometer measure is reported in 1000 km which is of minor importance because of a long period between the readings (up to four years for passenger cars and two years for lorries). The resulting dataset from SynsData is complemented by information about the Company Registration Number from the annual Motor Register. Based on this number the sector and detailed branch is found from two other registers, a register with account data for firms and a register of employees. Unfortunately the project did not have access to the full company register with branch codes, the used datasets being partly incomplete because companies without employees are missing in case they do not have to deliver detailed accounts to the tax authorities (It is only compulsory for private businesses and only in case of a minimum turnover).

The daily mileage as extracted from SynsData is as suggested in XXX (removed due to double blind review) recalculated to kilometres per working day, which is assumed to be 225 days on average (5 days a week and 45 weeks per year; vacations and public holidays this way being excluded). The number of travelling days might be higher for lorries and fleet vehicles used by several employees and therefore driving during holiday seasons and weekends too. However, by using 225 days to calculate the daily average travel distance we are more on the safe side and do not underestimate the daily mileage.

Data sources for the analysis of Germany include publications and statistical data provided by the German Federal Motor Transport Authority (KBA) as well as empirical survey data from Motor Vehicle Traffic in Germany (KiD 2010). The KBA among other tasks manages the German Central Vehicle Register including all registered vehicles with all information such as number plate, power, payload, total weight etc.). The survey KiD 2010 (WERMUTH et al. 2012) is a nationwide representative survey of vehicle owners on the usage of motor vehicles conducted through one year. The survey focused on business and commercial traffic and recorded all passenger and freight trips by passenger cars as well as lorries with a pay load up to 3.5 tons. From the survey can be extracted daily mileage, trip length, the length of each pause between the trips and the number of trips and pauses. Results from the survey are average figures for a year for the vehicle stock. Only days with a trip are included in the analyses. The resulting data includes branches as these are reported by the respondents and therefore not necessarily in accordance with the official classification system of branches in the Motor Register.

According to the scope of the paper the different types of vehicles in this paper are examined with focus on three main types of vehicles. Firstly, we consider passenger cars with commercial owners. The second group of examined vehicles are commercial LDVs with up to 3.5 tons GVW. The third group is lorries with a GVW up to 12 tons. Due to differences in statistical subcategorization it has been necessary for the analyses of the German vehicle mileage to use a special group of LDVs with less than 3.5 tons pay load. As the pay load is around 40% of the GVW LDVs with a pay load less than 3.5 tons are comparable with LDVs with a GVW of less than 9-10 tons. They can therefore be compared with the Danish LDVs up to 12 tons.

3 Results

The two analysed countries, Denmark and Germany, differ in many aspects. On the one hand Germany has approximately fifteen times as many inhabitants (82 million) as Denmark (5.5 million). On the other hand Denmark has a higher GDP level per capita (€ 37,000) than Germany's (€ 29,000). The Danes however only have 355 private passenger cars per 1000 inhabitants whereas the Germans have 543. In both countries the most important economic sector is the Manufacturing sector. It is followed – in slightly different order – by the Wholesale and Retail trade sector, the Real estate activities sector and the Human health sector.

3.1 The commercial vehicle stock

The number of commercial vehicles per inhabitant in Germany is higher than in Denmark (85 and 75 vehicles/1000 inhabitants, respectively), see Table 1. Most interesting is that the number of commercial passenger cars per inhabitant in Germany is nearly the double of the level s in Denmark (52 versus 28 vehicles/1000 inhabitants) whereas the number of vans with a GVW up to 3.5 tons is more than three times higher in Denmark than in Germany (43 versus 14 vans/1000 inhabitants).

Table 1 Registered passenger cars, vans and LDVs by economic sectors.

		Denmark (end 2010)				Germany (end 2011)			
NACE	Sector (short)	Passen-ger cars	Vans 0-3,5t GVW	Lorries 3,6-12t GVW	Share of all vehicles	Passenger cars	Vans 0-3,5t GVW	Lorries 3,6-12t GVW	Share of all vehicles
A	Agriculture	1,939	13,720	462	4%	38,563	20,248	5,736	10%
B	Mining	249	326	14	0%	7,466	3,622	1,215	0%
C	Manufacturing	12,251	19,387	663	8%	633,751	127,596	29,585	12%
D	Electricity, gas	592	2,048	127	1%	36,171	28,802	2,124	1%
E	Water supply	259	1,479	301	1%	24,897	17,697	5,049	1%
F	Construction	5,394	8,0137	1753	22%	218,417	192,374	32,607	7%
G	Wholesale and retail trade	47,003	41,266	1782	23%	714,316	135,557	37,762	14%
H	Transportation and storage	7,219	9,536	1185	5%	150,168	84,763	34,402	6%
I	Accommodation	1,235	4,498	36	1%	44,138	7,878	692	1%
J	Information, communication	6,759	4,079	42	3%	61,509	10,125	527	1%
K	Financial, insurance activities	3,447	1,466	24	1%	62,632	2,195	169	1%
L	Real estate activities	2,095	5,004	106	2%	12,788	2,610	238	0%
M	Professional, scientific services	6,942	7,817	144	4%	35,182	2,250	150	1%
N	Administrative and support	12,179	19,592	617	8%	411,611	79,882	27,324	7%
O	Public administration	2,902	635	57	1%	128,959	44,560	13,363	4%
P	Education	3,111	1,805	98	1%	9,529	665	126	0%
Q	Human health	6,876	4,258	126	3%	175,209	10,346	1,870	3%
R	Arts, entertainment	692	1,251	52	1%	19,564	2,514	559	0%
S	Other services	1,409	2,963	92	1%	1,482,264	430,467	83,808	31%
U	Extraterritorial organisation	-	-	-	-	6,125	1,030	292	0%
	Sector not revealed	18,264	19,150	1,376	10%				
Commercial vehicles in all[1]		154,743	243,912	9,950	100%	4,273,259	1,165,077	277,598	100%
Commercial vehicles per 1000 inhab-itants		*27.62*	*43.4*	*1.8*	*75.34*	*52.11*	*14.20*	*3.38*	*84.55*

Source: Denmark – Own calculations on data from Statistics Denmark. [1]From Statistikbanken, possibly including vehicles not actually registered Germany – German Federal Motor Transport Authority (KBA).

Table 1 furthermore shows that the vast majority (88%) of the Danish commercial vehicle stock up to 12 tons are vans with a GVW of 3.5 tonnes or less. 33% of the vans are registered in the construction sector. For all vehicle types, the wholesale and retail sector, which includes car dealers, owns 23% (for passenger cars 33%). The Manufacturing and the Administration and support sectors represent 8% each. Half of the lorries belongs to Construction, Trade and Transportation sectors. For 8% of the vans and 13% of the passenger cars the sector could not be established.

For Germany the most dominating sector is Other service activities (S) representing close to one third of the commercial vehicles for all three listed vehicle types. Other sectors with more than 10% of the commercial passenger cars are the wholesale and retail trade and the manufacturing sectors. More than 10% of the vans up to 3.5 tons are registered in each of the Construction, the Wholesale and retail trade and the Manufacturing sectors. About 20% of the lorries between 7.5 and 12 tons gross vehicle weight are registered in the Transportation and storage sector.

The following analyses take their outsets in the sectors with most vehicles, which are not the same in the two countries.

3.2 Travel distances of commercial vehicles

The first step of the analyses is to determinate the distribution of average daily travel distance separately for passenger cars and LDV's for each economic sector. In Germany it is even possible to figure out the distribution of the average trip length on a specific day. For Denmark it is only possible to calculate an average daily travel distance over a long period which results in a much lower variance in the daily mileage.

3.2.1 Germany

For Germany the analyses are made for passenger cars with commercial owners only and for LDVs with up to 3.5 tons pay load separately. Only vehicles used at the reference date are included, which means that weekends are normally left out of the calculations. The same is the case with holidays for vehicles used by one employee.

Table 2 shows that about 50% of the passenger cars with commercial owners are driven less than 50 km and even 71% are driven less than 100 km at the surveyed day. The sectors with the considerably highest shares of passenger cars with daily mileages below 50 km and below 100 km respectively are the Human health and social work activities sector (Q) (67% drive less than 50 km and 89% drive less than 100 km), the Agriculture sector (A) (72% drive less than 50 km and 81% drive less than 100 km), and the Real estate sector (L) (59% drive less than 50 km and 86% less than 100 km).

Table 2 For passenger cars with commercial owners and LDVs by stated economic activity in Germany in 2010: Share of daily average mileage less than 50 respective 100 km. Mileage and Trip distribution (see Table 1for meaning of NACE codes)

	Passenger cars with commercial owner						LDVs (up to 3.5 tons pay load)					
NACE Code	< 50 km	< 100 km	Daily mileage per car [km]	Mileage [million km]	Average No. of trips/car/day	Average trip length [km]	< 50 km	< 100 km	Daily mileage per car [km]	Mileage [million km]	Average No. of trips/car/day	Average trip length [km]
A	72%	81%	79.7	674	4.9	16.4	74%	92%	45.9	687	8.9	5.2
B	24%	37%	127.5	297	5.4	22.8	53%	81%	71.4	58	10.1	7.3
C	49%	64%	149.7	9,407	3.8	39.5	50%	71%	88.0	2,869	7.7	11.5
D	49%	81%	66.8	600	6.8	9.8	57%	80%	63.4	517	5.6	11.2
E	38%	64%	122.1	809	3.1	38.5	52%	85%	60.7	502	10.7	5.7
F	56%	79%	98.0	6,647	3.7	26.5	59%	80%	68.0	7,823	4.3	15.9
G	53%	69%	108.3	9,837	4.4	24.4	41%	65%	109.5	3,933	10.1	10.8
H	42%	57%	104.2	2,413	11.8	8.8	36%	54%	156.5	5,664	43.2	3.6
I	45%	76%	45.2	348	4.8	9.4	63%	88%	56.3	235	15.0	3.7
J	36%	72%	110.6	2,114	3.0	36.4	46%	71%	73.9	263	16.7	4.5
K	34%	68%	103.9	1,215	5.0	20.9	45%	67%	67.9	28	27.1	2.5
L	59%	86%	59.5	478	4.0	14.9	78%	91%	37.0	138	8.0	4.6
M	43%	60%	135.7	3,900	3.0	45.3	37%	60%	112.9	603	4.7	24.1
N	34%	66%	122.4	3,363	5.5	22.1	51%	71%	90.8	1,732	7.8	11.5
O	48%	74%	81.1	2,014	10.1	8.0	69%	89%	47.7	635	13.0	3.7
P	28%	35%	100.6	1,011	13.1	7.7	52%	78%	77.3	53	14.3	5.3
Q	67%	89%	62.1	4,110	9.8	6.4	52%	78%	75.9	390	17.4	4.3
R	55%	76%	98.2	188	3.0	31.3	59%	75%	104.1	95	10.2	10.6
S	51%	77%	122.5	3,850	6.5	19.0	50%	69%	97.4	1,402	15.0	6.5
U	40%	47%	72.6	47	2.6	23.5	28%	72%	50.5	4	3.5	n/a
Total	**50%**	**71%**	**103.6**	**53,322**	**5.7**	**18.1**	**53%**	**74%**	**85.0**	**27,631**	**11.7**	**7.3**

Source: KiD 2010, own calculation

Figure 1 and Figure 2 show the cumulative distribution of the daily mileage per car for selected economic sectors for passenger cars and LDVs under 3.5 tons pay load, respectively. The selected sectors are chosen with respect to their relevance in terms of mileage, vehicle stock, and total mileage (Table 2).

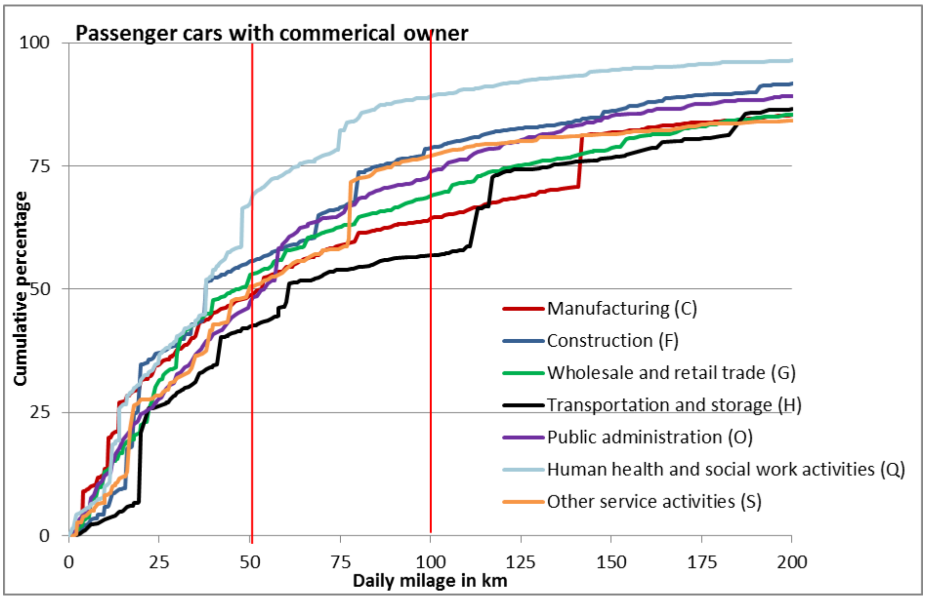

Figure 1: Cumulative distribution of daily mileage of passenger cars [Source: KiD 2010]

For passenger cars Figure 1 shows a daily driving distance shorter than 50 km for 50% or more of the vehicles for the selected sectors with a high number of vehicles. The highest share of vehicles with a daily mileage under the 100 km threshold is besides the Human Health and Social work activities sector, the sectors Others, Construction and Public Administration with relatively high shares around 75% of the cars driving less than 100 km per day. The transportation sector, the Manufacturing sector and partly the Wholesale and Trade sector have a high share of vehicles driving longer than 100 km per day on average. Even though the Others sector has a high share of vehicles driving less than 100 km the distribution of vehicles driving over 100 km is more similar to the Transportation and the Wholesale and Retail trade sectors.

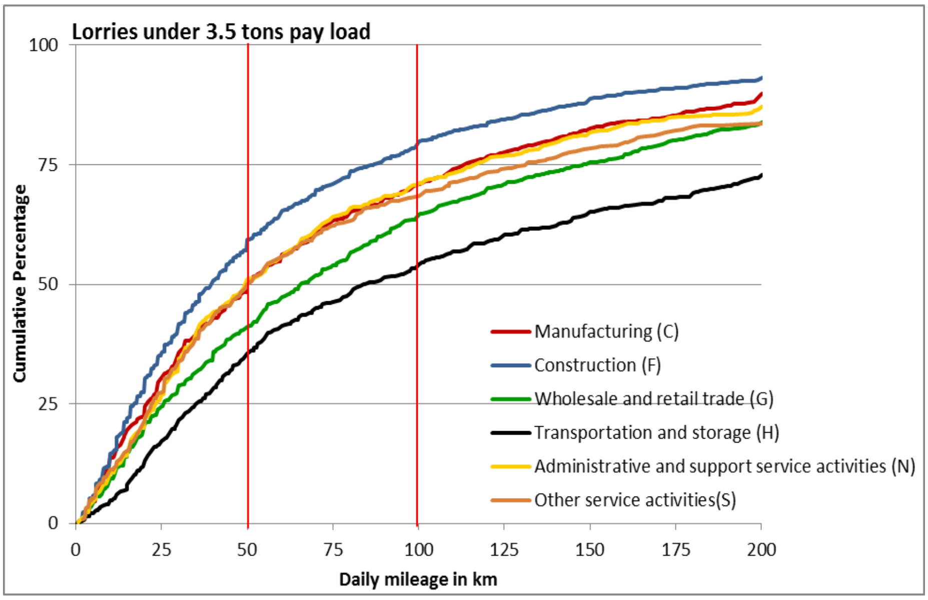

Figure 2: Cumulative distribution of daily mileage of lorries under 3.5 tons payload [Source: KiD 2010]

For LDVs with fewer than 3.5 tons permissible payload a higher share drives less than 50 km (54%) but a lower sharedrives less than 100 km (76%) compared to passenger vehicles. As with the passenger cars the Real estate sector with 78%, the Agriculture sector with 74%, and the Public administration sector with 69% are the sectors with the highest share of the vehicles driving less than

50 km on average daily distances. Only 8-11% of the LDVs in these sectors drive more than 100 km at the actual survey day (see Table 2).

Of the large sectors included in Figure 1 the Construction sector has the highest share of vehicles driving less than 50 km as well as 100 km. It is the only sector with more than 75% of the vehicles driving less than 100 km per day in average. The graphs for the sectors S, C, and N are nearly identical, with shares around 50% for vehicles with a daily mileage less than 50 km and shares around 70% for vehicles driving less than 100 km per day. As with the passenger cars in the Other services sector has a higher share of vehicles driving very long daily distances.

The driving pattern of LDVs (under 3.5 tons pay load) is quite different from the passenger cars'. More trips per day are conducted and as a consequence more stops are made. Trips are generally shorter (Figure 2). This is especially the case for – again - the Transportation and Storage sector (H) with its strikingly high number of trips per day (43.2) accounting for the highest share of the trips (41%) but only 20% of the mileage. The opposite is the case with the Construction sector with average trip lengths of 16 km accounting for 28% of the mileage and 13% of all trips. The sectors S, C, and N account for about five percent of the trips and mileage each, except for the manufacturing sector with overall 10% of the mileage.

3.2.2 Denmark

Due to the methodology of gathering information about travel patterns by reading the odometers the results for Denmark in Table 3 are based on average figures during a period up to four years calculated with 225 working days. The table shows the share of vehicles driving less than 50 and 100 km, respectively, the mean travel distance and the number of observations the calculations are based on. For sectors with very few observations figures are excluded. Figure 3 is furthermore showing a more detailed distribution of travel distances for selected sectors.

Table 3 Share of daily average mileage less than 50 km and 100 km and the number of vehicles included in the calculations for passenger cars, vans and lorries under 12 tons GVW by economic activity in Denmark in 2010

		Passenger cars				Vans 0-3.5 tons				Lorries 3.6-12 tons			
		< 50 km	<100 km	Mean km	Obser-vations	< 50 km	<100 km	Mean km	Obser-vations	< 50 km	<100 km	Mean km	Obser-vations
A	Agriculture	26%	67%	87	913	35%	81%	71	8,595	50%	85%	62	1,182
B	Mining				20				147				31
C	Manufacturing	18%	52%	108	1,911	38%	75%	74	8,000	33%	58%	98	1,752
D	Electricity, gas				42	62%	90%	51	719	46%	88%	55	328
E	Water supply				64	46%	83%	62	552	25%	62%	88	755
F	Construction	23%	65%	91	1,382	37%	81%	69	34,106	43%	80%	67	4,712
G	Wholesale, retail trade	27%	71%	87	5,978	33%	73%	79	16,364	26%	52%	111	4,441
H	Transportation and storage	6%	12%	338	6,347	30%	63%	110	3,368	20%	40%	165	2,818
I	Accommodation	34%	73%	81	339	38%	79%	71	1,850				65
J	Information, communi-cation	24%	60%	94	782	36%	77%	72	1,160	65%	78%	58	113
K	Financial, insurance activities	27%	75%	79	460	41%	78%	70	533				73
L	Real estate activities	36%	72%	81	700	42%	83%	65	2,642	53%	82%	61	245
M	Professional, scientific	27%	68%	84	1,727	37%	76%	74	3,209	50%	83%	60	321
N	Administrative, support	21%	64%	92	1,444	27%	71%	82	7,503	40%	74%	82	1,611
O	Public administration	35%	79%	76	1,560	52%	84%	60	381	60%	80%	98	155
P	Education	30%	58%	108	1,536	60%	91%	51	915	65%	93%	41	224
Q	Human health	39%	75%	74	2,609	54%	89%	55	1,939	57%	90%	49	348
R	Arts, entertainment	33%	73%	85	228	40%	80%	69	577	67%	94%	42	127
S	Other services	41%	84%	66	503	35%	75%	76	1,224	14%	33%	177	254
	Sector not revealed	34%	63%	114	17,005	41%	97%	66	18,491	47%	63%	105	4,599
	Total	27%	59%	103	45,550	45%	80%	70	112,275	38%	65%	85	24,154

Source: Own calculations on Statistics Denmark's Synsdata at the end of 2010 and several sourceson sectors

Danish commercial passenger cars drive longer on average (103 km per working day) than commercial vans and lorries (see Table 3). The shares driving less than 50 km (27%) and less than 100 km (59%) are both much higher than for vans and lorries. It is opposite to Germany too, where passenger vehicles drive least. In no sectors (except the small Other services sector) passenger cars drive less than the vans in the same sector. Most extreme is the Transportation sector in which the average distance is 338 km and only 12% of the cars drive less than 100 km. 69% of the observations in the sector stem from taxies and further 15% from other person transport with e.g. tourists. For these companies it is misleading to calculate distances based on 225 working days, as they are used all year round by several drivers, which results in a daily average of 313 km. Figure 3 shows a group of sectors in which the passenger cars have more or less the same mileage distribution. Passenger cars in the Manufacturing sector drive more than this middle group and the Health care sector drives less.

The group of vehicles for which the sector could not be established has an unclear distribution. It is our assumption that the group consists mainly of self-employed with no employees so that the car is driven by the owner. Some of these cars drive very little while others drive very much. The latter group is possibly dominated by self-employed taxi drivers.

The lorries with a GVW up to 12 tons drive more than the vans. They are mainly driven by professional drivers and a high share is probably driving on more than 225 days so that the share driving less than 100 km is a little under-estimated. The distribution of daily mileage is quite different for the sectors with the Transportation sector driving most (dominated by goods distribution) followed by the Wholesale and Trade sector which also includes many lorries distributing goods to shops and private households. Lorries in the Construction, the Professional service and the small Others services sectors drive least. As with the passenger cars there are two main groups of self-employed vehicle owners, one driving very little and one driving much, possibly from the Transportation sector.

The vans drive least. A smaller group of vans with a GVW under 2 tons has a mileage distribution which is little sector specific (see also Figure 3) even small vans in the Transportation sector drive as the average. The average distribution of the small vans is only a little different from the larger vans. Of the vans between 2 and 3.5 tons one sector (Transportation) has a higher mileage than the average and three groups have a lower average, the Health care sector, the Construction sector and the self-employed. The self-employed van owners probably consist of a high share of construction workers running their own businesses with private home renovation and repair. Shortest distances are driven by the Health care sector with 65% driving less than 50 km and 90% driving less than 100 km. Around 37% of the big vans in the construction sector and 45% of the self-employed drive less than 50 km and more than 80% drive less than 100 km.

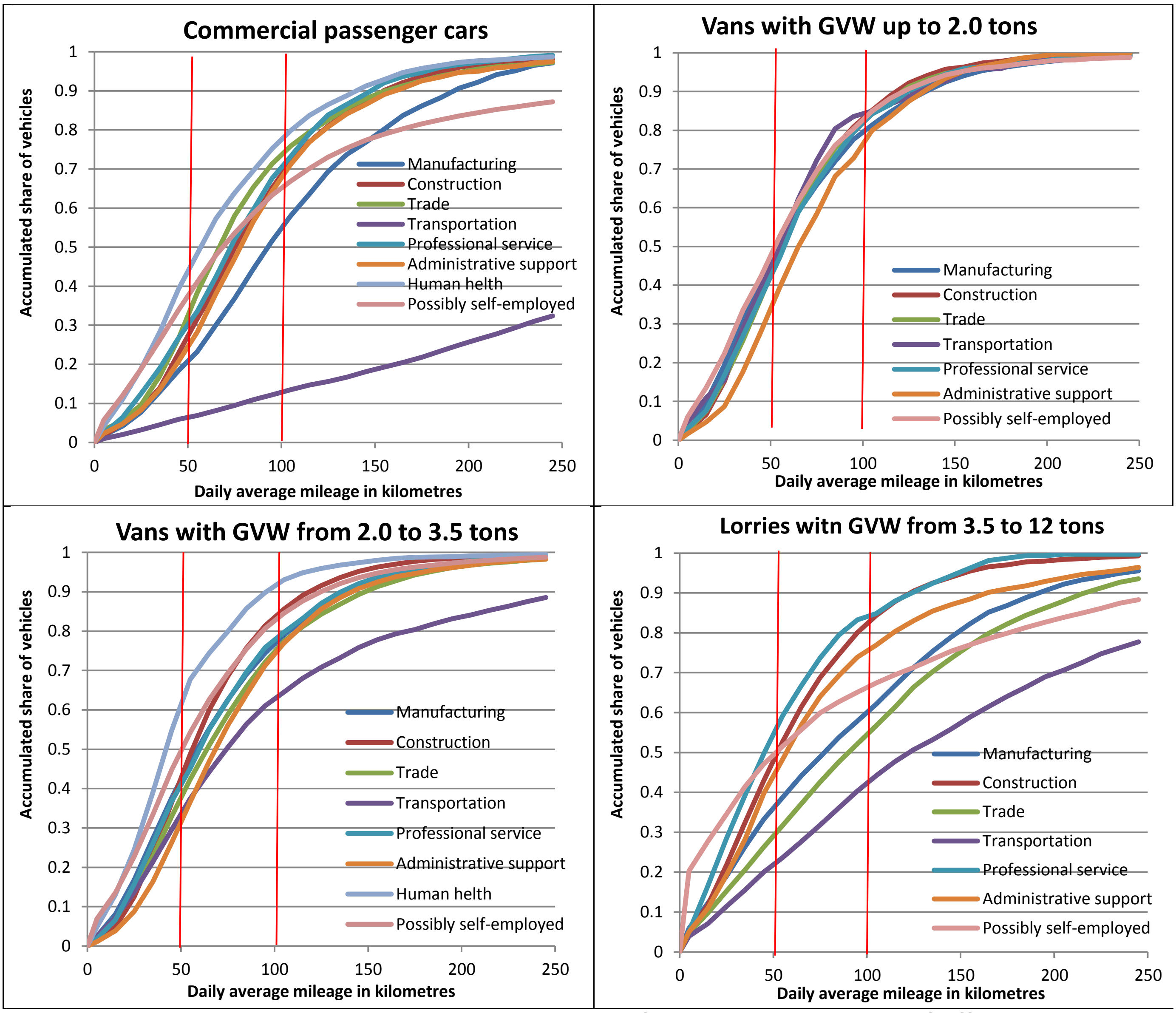

Figure 3: Accumulated average daily mileage by economic sector for passenger cars and vans of different size, Denmark

3.3 Inter-day variation of travel distances

Average figures as presented above are not fully useable for the assessment of the fleet's suitability for electric mobility. A shift to an EV is only interesting for a businessman if the car is able to cover also days with longer distances than the average value. It is therefore the maximum mileage during a long period, which sets the threshold for the options. In this subsector results from daily data analyses over a longer period from some weeks to half a year are presented.

3.3.1 Germany

For Germany examples of driving patterns were analysed in cooperation with four nursing companies (Human health sector (Q)) by using GPS devices logging the daily distances, trip lengths and stop lengths over a period of two to three weeks. The companies' fleets feature between 8 and 22 vehicles. In total more than 1,000 vehicle days and more than 8,000 trips were recorded.

For these nursing services 66% of all vehicles have not been driven above 100 km per day during the survey period. The share varies between 25% and 93% (Table 4). The average daily mileage for all vehicles is 47.0 km. Companies 1, 3 and 4 show comparable average daily mileages between 37.6 and 49.1 km. In the fourth company the vehicles drive 74.9 km per day on average. The standard deviation of the daily mileage of the four companies is between 24.7 and 47.1 km.

Table 4 Company – Number of vehicles – average daily mileage – variance – share of vehicles driving less than 100 km in all analysed days.

Company	No. of vehicles	Average daily mileage [km/day]	Standard deviation	Share of vehicles below 100 km [%]
01	15	37.6	35.7	93.3
02	8	74.9	24.7	25.0
03	8	49.1	47.1	62.5
04	22	42.5	31.2	63.6
All companies	53	47.0	33.9	66.0

In company 1 only one vehicle performed daily mileages longer than 100 km. 28% of the stops of this vehicle are longer than 20 min and only 5% of the stops are longer than 60 min. Thus only fast charging would be an option to be considered as EV potential. In company 2 six out of eight cars are used for more than 100 km per day. During the survey period only three cars from company 3 were used for more than 100 km in one working day in all. Eight out of 22 cars in company 4 made more than 100 km in at least one day during the survey period. Due to stop times mostly below 60 minutes a substantial none of the cars can recharge without charging by a fast charging station. Consequently our results show significant inter-day variations within the sector.

3.3.2 Denmark

For Denmark vans or passenger cars from companies in different sectors have been followed during periods ranging from a few weeks to half a year: two taxi companies and two companies in the Wholesale and trade sector providing delivering service, two companies in the Construction sector and one in the Professional service sector.

Data for vans is collected from three construction / service companies in the Copenhagen area, an electrician, a decorator and a chimney sweeper. For two companies data are collected by GPS and for one from the company's vehicle steering system.

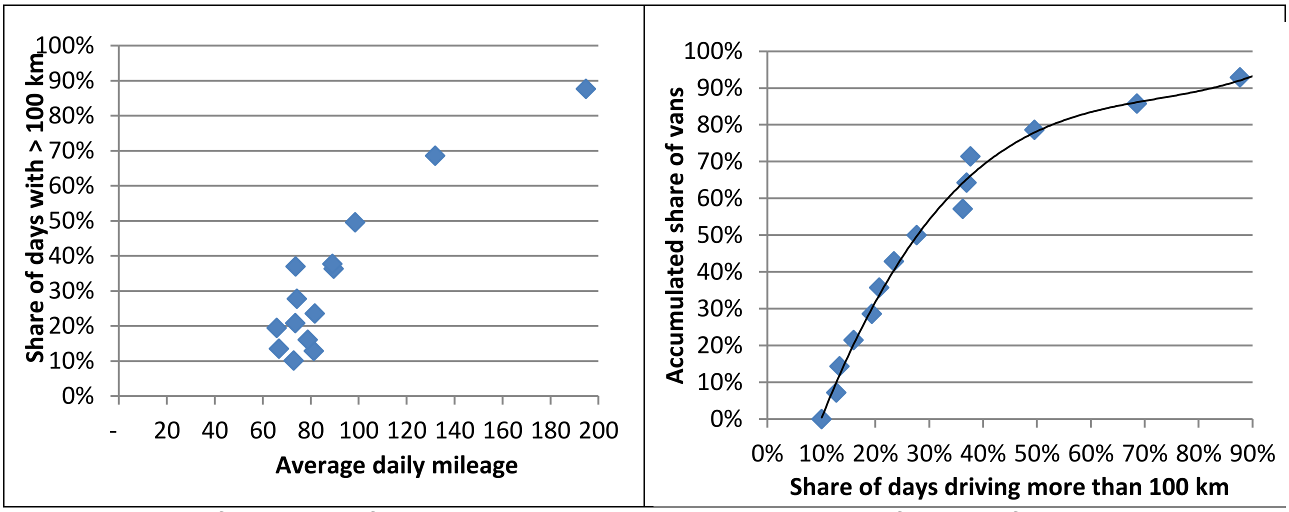

Figure 4 To the left the share of days the vans driving more than 100 km as a function of the average daily travel distance. To the right the share of vans driving longer than 100 km for a given share of the analysed period.

Figure 4 illustrates some results from the two companies in the Construction sector, represented by two vans smaller than 2.0 tons and 12 vans of 3.5 tons driving for 4 and 6 months, respectively. The two companies are located in the western suburbs of Copenhagen and serve a wide area in the region. In 68% of the working days of the analysed vans, the mileage is less than 100 km. 2 of the vehicles drive more than 100 km per day in average and one is close to 100 km on average. However, all the vans drive more than 100 km in at least 10% of the analysed period and several drive longer on half of the days.

For both companies the employees use the van for commuting. Most of the employees live in a radius of 10-20 kilometres from their company, but two live much further away. Very often the employees drive directly from their home to the costumers and most often they do not visit the company address more than a few times during the week.

It is analysed if it is possible to make the vans more suitable for electric mobility by allowing them to charge during the day. However, the pauses from work duties are typically too short for the charged power to be enough for overcoming the daily mileage if the vehicles were electric.

The earlier mentioned chimney sweeper is located in the municipality of Copenhagen and has license to serve all houses in a certain area of the municipality. The small vans used by the company are parked at the company's address overnight. Two vans are followed during two and a half weeks each. On 40% of the days the vans drive 50-60 km, on 40% less, and on a few days they drive more. Only one car drives more than 100 kilometres. It happens once when it drives out of the district, probably to collect something from a supplier.

Figure 5 shows the distribution of the average daily mileage of all vans from different sub-sectors of the Construction sector similar to the analysis of all Danish vans in the above section. More than 70% of the vans owned by the companies in the traditional construction sector drive less than 100 km per day, whereas only 15-20% drive less than 50 kilometres in average. The travel pattern of the different sectors' vans seems to be quite similar. Other groups in the Construction sector like building contractors of different kinds drive a little longer (not shown). These results show that the two detailed analysed companies in the Construction sector drive a little longer than similar companies on average, probably due to a location in the Copenhagen region. On the other hand, the chimney sweeper might be more similar to companies serving a certain district for repair, homecare etc.

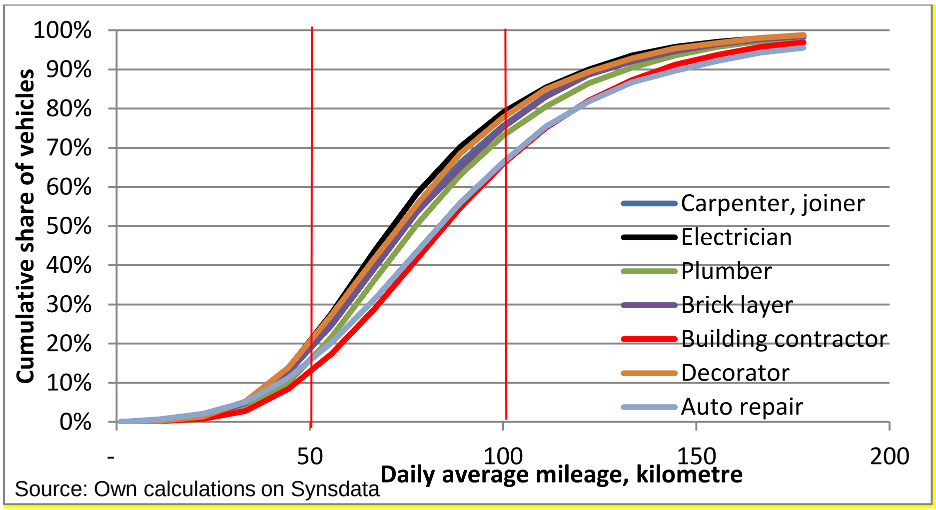

Figure 5 Daily mileage of vans by different professional groups in Denmark

Travel patterns of taxies from two cooperations of small taxi firms, the one with primary basis in Central Copenhagen (190 taxies), the other with costumers in different towns at Zealand (9 taxies) are analysed by means of the fleet management system and GPS loggers, respectively. The two companies that deliver food and groceries to private households serve the Copenhagen region (47 lorries followed by GPS loggers) and the whole of Denmark (56 18-tons trucks followed by the company's fleet steering system). For all vehicles, daily energy consumption is calculated. The presented results are referred from the project report (reference removed due to double blind review).

The taxies' driving behaviour is in good accordance with the rest of the sector as described above. Only in 10 respectively 23% of the vehicle-days the mileage is less than 100 km and in 60% respectively 75% of the days the taxies drive at least 150 km and several days more than 500 km. A few taxies – probably owners with no employees – have a daily mileage less than 100 km most of the days. Only on 7% of the days the taxies which drive during the summer period would be able to manage without charging during the day. In many cases fast charging would be needed for the car to be ready for the following day in case they were replaced by an EV. The company driving during the winter period has no days where it would be able to manage without charging during the day.

For the nation-wide delivery service only 7% of the vehicle-days are shorter than 100 km. 83% of the days the trucks drive more than 150 km and 25% of the days even more than 500 km. The other delivery company drives less. However, they lease their lorries from a transport company so that they can deliver in the morning. The rest of the days the lorries are probably in use by others. But even in 'their' part of the vehicle-day, 1/3 of the lorries drive more than 100 km. Only the company with the short delivering period would manage without charging during the day in case of a shift to EVs.

4 Discussion

In this section we will on the one hand assess the empirical results related to the suitability of commercial vehicles in different target groups to shift to electric mobility. On the other hand we will discuss the effect of current policies and promotions in relation to development of the commercial fleets in a more sustainable direction.

4.1 Results from the analyses

Considering the size of the vehicle stock, the overall mileage and the average daily travel distances, especially vans in the Construction sector and passenger cars in the Health care sector are in both countries most suitable for a shift to electric mobility. For Denmark the vans from the Human health care sector might be relevant too. For Germany both passenger cars and LDVs with a payload up to 3.5 tons in the construction sector seem to be suitable for a change. The same is the case with a share of vehicles in the Other service sector. This sector is very small in Denmark, but the few cars used by the sector drive less than others. The difference in size seems partly to be due to a different classification of the firms in NACE groups.

In Denmark commercial passenger cars except for the mentioned groups and a smaller share owned by self-employed without employees - drive very far and only few are suitable for electric mobility. Lorries over 3.5 tons GVW are not suitable either.

For vans and small lorries in the Administrative and support service activities and the Manufacturing sector it seems to be particularly relevant to shift to EV's in Germany too. For Denmark a small share of the vans in these sectors and in the Professional service sector might be relevant, but it is necessary to carry out a more detailed study.

When only considering the average daily mileage, at least half of the German commercial vehicles in the mentioned sectors and probably closer to 2/3 can be shifted to EVs since at least half of them drive less than 50 km and more than 70% drive less than 100 km. In Denmark a slightly smaller share of vans in the chosen sectors drive less than 50 km per day. It might therefore be a lower share of Danish vans that can be replaced by EVs.

When including the inter-day variation in the daily mileage, the share which could be replaced, is substantially lower. In most of the companies in Denmark and Germany many cars exceed the current travel range of EVs - at least at some days during the analysed period. Indeed, the analyses are far from being representative for the part of the commercial sectors, which are shown to be relevant for electric mobility. Consequently the share of the vehicles which can be replaced by an EV cannot be stated but it is clearly lower that than the above-mentioned shares.

The German Wholesale and retail trade sector, which has the second highest number of registered vehicles, the highest share of total mileage and approximately 70% of cars driving less than 100 km per day might be relevant for electric mobility, too. However, the sector is very complex, which makes the picture blurred. A very high share of new registrations, especially of the passenger cars (more than 90% in Germany and a third in Denmark (own calculations on data in the annual version of the Motor register), indicates that automobile dealers represent a substantial part of the vehicles in the stock only keeping the cars until they are passed on to the costumers. Furthermore, an unknown share of the companies has a driving behaviour similar to that of the Transportation sector as can be seen with the example of the two food delivery companies in section 3.3.2. Due to this the suitability of the sector cannot be assessed. Finally, the Transportation and storage sector is the least suitable sector, especially for Denmark.

4.2 Policy assessment

The actual low deployment of EVs in in general and in the commercial sector especially (see section 1.1) might be due to both economic and practical reasons. To foster the use of electric vehicles and their market diffusion in commercial transport different policy options from the national as well as the local governments can be seen. Measures can influence the purchase price of EVs or the cost of operation to compensate for the higher price for EVs due to the expensive batteries. Direct subsidies can be given during a certain period by a reduction in the annual tax or purchase tax or by special depreciations for company cars. The cost for vehicles with internal combustion engines (ICE) may also be raised by higher CO_2 specific vehicle taxes or higher fuel costs by higher fuel taxation. As described in the introduction such compensations are already the case in several countries.

In the following section we discuss other initiatives focused on commercial vehicles. The initiatives can be of both practical and economic character.

4.2.1 Technical issues of importance for the deployment of commercial EVs

As unveiled in section 3.3 many companies have a car fleet driving well below the daily mileage threshold and therefore apparently suitable for electric mobility. However, sometimes the cars drive longer distances than the driving range during the day. To overcome this it might be a possibility to keep a few conventional cars in the fleet that can be used for extra-long trips. Vans serving a certain district as the chimney sweepers and not commuting by the vehicle might often drive rather few kilometres per day. They might be more relevant than companies serving random costumers. It might be possible to organise which routes should be served by the EVs and which by a conventional car in case of a mixed fleet. For this purpose a fleet managing system to optimise or at least organise the distribution of daily mileage on the cars in the fleet might be useful. This question is analysed in other parts of the actual project.

Another option is to recharge the EVs during the day either with a fast-charging facility en route since the majority of the stops are too short to recharge a substantial portion with a slow-charging facility or by the costumer during the duty either in the private premises or at a public charger close to the costumer. None of the available options are optimal. Charging en route takes time from the duty and might only be an option during e.g. a lunch break. Only with a very dense charging network, charging close to the costumer is an option and therefore only relevant in dense city areas and in areas with dedicated charging poles. Charging at the location of the costumers might be difficult in relation to billing in case of private households and small companies and an agreement need to be made with the costumer. At construction sites it might be included in a tender and therefore easier to handle.

Another technical restriction for commercial transport is the higher weight of the vehicles due to the battery weight. This additional weight can reduce the pay load by 200 to 400 kilos. Especially vans with a GVW close to 3.5 tons are remarkably affected by the reduced pay load. The advantage of these vans is that they can be driven with an ordinary passenger car license (licence type B). For heavier vehicles a special truck driving license is needed. In the Construction sector some vehicles are used to carry very heavy materials (e.g. masons) for which the pay load is of significant importance. Others bring heavy tools or an entire workshop including heavy material (e.g. plumbers). However, most often the pay load of the van is of minor importance as the loaded weight is mainly low. Especially in the parcel distribution sector most parcels are lightweight (e.g. 1-5 kg) due to the high cost per shipped kilogram. Instead the volume of the car is of importance resulting again in a van at 3.5 tons GVW. If batteries are added to the car, it cannot be driven with a license type B. These big vans will therefore suffer from limited battery capacity and thereby shorter travel range than what is interesting for the companies.

Since the beginning of 2015 a change in the German driving licence regulation allows persons with a driving licence class B to drive electric vans with GVW up to 4.25 tons (see Bundesministerium für Verkehr und digitale Infrastruktur, 2014). This initiative might be an important support to the use of electric vans in companies for which either weight or size of the van is of importance, because it makes it possible to add heavy batteries to the big vans close to 3.5 tons GVW and thereby increase the travel range. The new German rule is too new to evaluate if the change has attracted more companies to buy EVs.

4.2.2 The influence of tax policy

The results of the analyses show substantial differences between Denmark and Germany in both the composition of the car park and the mileage of the car stock. The differences in mileage are found for all sectors and for both commercial passenger cars and vans. These differences are assessed mainly to be due to a very different structure of vehicle taxation in the two countries.

Due to a very high purchase tax passenger cars in Denmark are 2-3 times more expensive compared to Germany where no purchase tax is added. Also the VAT in Germany is lower. On the other hand, vans are imposed with a lower purchase tax in Denmark. However, if the backseats are removed from passenger cars and few other smaller adjustments are done, the car is considered a van with a lower purchase tax and a small annual fee for the allowance to drive privately too (Skatteministeriet, 2015d).

Furthermore, the rules for taxation of company passenger cars used by employees are not very favourable for the choice of EVs. The company is allowed to pay all maintenance and running cost for the employee, but for the user of the free car 25% of the value of the car up to €40,000 and 20% of the remaining value is treated as taxable income (Skatteministeriet, 2015a). On top of this, since 2010 an environmental fee is added with the purpose to make it attractive to choose a low emission car. It is therefore often more attractive for employees who drive an average daily mileage for the company to use his/her own car and get a tax free reimbursement per documented kilometre for business trips, because the reimbursement equals the marginal cost of owning and using a small family car. In Germany a monthly rate of 1 % of the value of a company car is treated as taxable income for private use of a free company car which equals only 12% of the value annually.

An effect of the rules is shown in section 3.2.2: commercial passenger cars in Denmark are the type of commercial vehicles with the highest daily average mileage. In Germany commercial passenger cars drive less than vans. Big sports utility vehicles (SUVs) and cars of similar size (over 2.5 tons) in a van version are often quite as representative and useful as a passenger car and therefore often used by salesmen with need for space, or by company owners and CEOs independent of their need for business travel.

The result of the generally extensive use of commercial passenger cars in Denmark is that they are generally not suitable for being replaced by electric vehicles. In cases where the company car is neither used for representative purposes nor privately the company will often choose a van instead of the passenger car. Their use might rather be comparable with the passenger cars in Germany and therefore, a potential attractive group for electric mobility in Denmark in line with the German passenger cars. This is probably the reason why small vans have the same mileage distribution independent of the sector (see Figure 3)

Another taxation rule of importance for the differences between the two countries is that employees who have a company van with a special adaptation (e.g. stalls for materials and tools) are allowed to use the van for their commuting trips without paying the company car tax for this (Skatteministeriet, 2015b). If they use it for further private transport they have to pay a minor tax for the extra kilometres. The result is as the example in section 3.3.2 shows that the construction workers and other engineers with changing costumers from day to day often use the van for commuting instead of leaving it at the office/workshop. The result is that some of these vans have a high daily mileage and are therefore not suitable for electric mobility. The share of suitable vans is thus lower in Denmark than in Germany.

An analysis based on more than 2,000 interviews with a representative sample of company owners in the two countries (and Austria) shows that the Danish owners are less attracted to introducing EVs in their vehicle fleets than the Germans (and Austrians). The described difference between the taxation structure and the resulting behaviour in the two countries might be a part of the explanation of the different attitudes (reference excluded due to double blind review).

4.2.3 Economic incentives to introduce EVs in a car fleet

Generally, companies should not be expected to change to electric mobility unless there is an economic incentive to do so. For some companies, the use of EVs can be seen as a promotion activity or as a part of a green image and they will therefore be first movers. However, in the long run it should not be expected that the EVs will be widely spread in the commercial sector if they are not economically feasible. On the other hand, in case EVs are feasible the commercial sector might very well be the first to adapt to electric mobility, because they are to a higher extent based on economic rationality than private consumers.

A German Government initiative to improve the propagation of commercial EVs was the change in the rules for taxation of private use of company cars to lower the operational costs of EVs due to higher list prices compared to conventional cars. It allows private users of company EVs to reduce the list price used for the calculation of the monthly rate of 1% of the vehicle price, which is treated as taxable income. For each kilowatt hour of battery size the vehicle price is offset by €500. In Denmark the mentioned environmental fee for taxation of company cars has the same effect, but it is directed against all kind of low-emission cars.

With the purpose of supporting the interest in purchasing an EV a Danish initiative has been to develop a calculator of the Total Cost of Ownership (TCO) to help people and companies assess if they have a travel pattern making the use of an EV attractive. This calculator is used in the paper at hand to assess the potential for commercial vehicles.

In Denmark, a Nissan eV200 van is approximately €6,500 more expensive than a similar ICE van, when considering also Danish registration taxes (without taxes and VAT, the EV is approximately €11,600 more expensive). This pattern goes across all vehicle types. In many companies, leasing is a preferred option of ownership. It adds flexibility and does not require the company to have large values invested in the car fleet. The TCO is, however, a little higher when leasing vehicles compared to ownership (from 6.5 to 15 cent per km using average uses of the vehicles and ranging from 5-15,000 km per year). Although the purchase price is higher, the TCO costs decline when the EV is used more, since travel costs are lower than for ICE vehicles. Also driving in urban conditions will favour EVs over ICE vehicles, since the energy use for ICE's is relatively higher at lower speeds. Overall a shift to electric mobility might be economically more or less equal in big cities when considering the full costs. But especially in the big cities the driving pattern might be less attractive due to a spread localisation of the costumers and the entrepreneurs.

4.2.4 Public incentives to promote commercial EVs

Not only economic incentives might influence the development of commercial EVs. Information activities might promote EVs too. Privileges can also be given to users of electric vehicles. These are the use of bus lanes, free parking and the allowance to enter restricted areas (e.g. pedestrian zones). Furthermore indirect benefits for the promotion of EVs can be given. This could be the support of research and development, the promotion of infrastructure development or special conditions for driving licenses.

The Swedish EV Procurement programme of special interest to vehicle fleets might be a reason for the higher number of EVs per capita in Sweden compared to Denmark and Germany because it increased public focus on commercial EVs (Wikström, 2015). In Denmark a dedicated programme for fleet vehicles was conducted too, but the companies were not followed so systematically as in Sweden and the evaluation is more random. (Energistyrelsen, 2015) shows that a main beneficiary of the support was municipalities that bought a few EVs each. The effect might therefore be less influential on the development. A draft paper in (Wikström, 2015) suggests public initiatives where special dedicated and engaged fleet managers from the local public administrations invite people to try an EV to become comfortable with it. Copenhagen Municipality is engaging in similar activities. By focusing the demonstration campaign to the business and especially the most relevant business types unveiled in this project a development might be initiated.

Initiatives in which vehicle fleet owners can get publicly paid and organised help to analyse the possible use and economy of EVs in their fleet might be especially relevant for small firms which do not have the economic power to overview the possible effects. The mentioned TCO calculator can be the first step in this a direction. Support in the transition process by specific assistance to the procurement process might furthermore improve the effect. The Danish rules about free support by an expert consultant to analyse the energy consumption of homes and provide suggestions for improvements could serve as a model.

4.2.5 Other policy issues of importance

The results from section 3 show a low theoretical potential for EVs in the Transportation and storage sector due to a high daily mileage and a high number of trips with multiple short stops, which makes recharging impossible. But especially for this sector the European Commission sets the objective to have emission free city logistics in major urban centres by 2030. Especially for this sector new concepts for parcel distribution (e.g. urban micro consolidation centres) and new electric vehicle concepts must be developed. Companies like DHL and UPS pilot projects using EVs for last mile parcel distribution. Recently DHL entered the market when they in 2015 took over then Aachen-based company Streetscooter, a company specialized in electrified vans for parcel companies, and produced cars for themselves. In Denmark the public mail (PostDanmark) has introduced EVs for mail delivery in certain areas (Ingeniøren, 2013).

5 Conclusions

In this paper the suitability of commercial transport for a shift to electric mobility has been investigated and commercial sectors with a high potential for use of electric vehicles in Denmark and Germany are identified.

For a detailed analysis we chose a three step research approach: 1) Analyses of vehicle registration records in Denmark and Germany regarding size of vehicle stock by commercial sectors 2) Statistical analyses of average daily mileage per sector based on a national driving survey in Germany and odometer meter readings in Denmark 3) GPS tracking with selected companies analysing inter-day variations in daily mileages, trip and stop lengths to uncover the robustness of the travel pattern related to electric mobility. The results of these three steps were discussed in light of a detailed analysis of the vehicle tax regulations and stimulus schemes to promote electric vehicles in both countries.

The resulting overall mileage and distribution of daily mileage showed that for both countries the Construction sector, the Health care service sector and the Other service sectors are suitable for the use of electric vehicles under the actual technological state of the art. The Manufacturing and Professional service sectors show a possible relevance regarding vehicle stock and suitability too. For Germany no significant difference between the use of passenger cars and LDVs could be shown and both kinds of cars are relevant. In Denmark vans are more suitable than passenger cars and bigger LDVs because a high share of the commercially used passenger cars and LDVs exceed driving ranges of available EVs. An exemption from this is the Health care service sector. The differences in the size of the commercial vehicle fleet and the mileage by different types of cars between the two countries are explained in the policy section, mainly by differences in vehicle taxation of passenger cars compared to vans without backseats. We assess that the Danish tax regulation is quite unique and consequently the results for passenger cars for Germany are the most applicable for other countries.

The analysis of the travel patterns of vehicles by GPS tracking in both the construction sector in Denmark and in the nursing services sector in Germany has shown significant inter-day variations in travel distances resulting in a share of days where the travel range is exceeded. Thus the share of vehicles which could be replaced by electric vehicles is lower than the statistical results predicted. On the other hand, companies which serve a certain small area and/or have fixed daily routes could easily shift their fleet to EVs. Most of them would possibly need a few conventional cars to cover trips which exceed electric driving ranges. Companies with huge catchment areas are less suitable for the use of EVs.

The results regarding the Transportation sector are ambiguous: A high share of companies drives long daily distances which is confirmed by analyses of Danish taxies and food distribution companies. Therefore most of this sector is not suitable for electric mobility. On the other hand vans of some parcel distribution companies used for city logistics exhibit daily mileages which mainly do not exceed electric driving ranges. Several companies have started to experiment with EVs, and DHL even produce their own cars.

The analyses unveil that the share of vans suitable for transition in Denmark is lower than for Germany too. This is due to a Danish right for construction workers and entrepreneurs to commute with the company car without paying tax for a company car. When analysing commercial driving patterns in other countries, one should be aware of the consequences of a similar rule.

Despite of tax incentives in both countries to buy EVs, a TCO analysis of EVs in Danish companies shows that tax reductions are not favouring EVs enough to make them more attractive than ICEs. EVs are only attractive for companies when the daily driving distance nearly exploits the electric range to its full extent. The analyses therefore shows a need for a longer driving range than the normal ones in today's vans to make them economically more feasible and to allow for a higher inter-day variation in mileage. Officially the range of a Nissan eV200 is 170 km, but in daily praxis the range is only 110 km in summer time and much less in winter. However, more batteries will increase the weight of the conventional 3.5 tons van which will hinder the entrepreneurs in driving the van with a normal driving license type B. Germany has therefore changed the driving license regulation so that electric LDVs with a GVW up to 4.25 tons can be driven by driving licence "type B" holders. In case this rule is adapted by many EU countries the car manufacturers might be more interested in a market for large electric vans with battery packs up to 500-700 kg. This could lead to a greater supply of different models with higher performance.

Other direct or indirect incentives mainly targeted towards companies in the identified sectors to increase the number of commercial EVs could be that municipalities together with chambers of commerce conduct information campaigns and testing schemes to allow these companies to experience the use of EVs in order to remove possible resentments. Offering free support to smaller companies that want to analyse the company's suitability for introduction of EVs in their fleet is another option.

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