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Analysis of charging behaviour when using battery electric vehicles in commercial transport

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Background

- In 2009 the German government announced the goal of 1 Mio. BEVs by 2020
  - Only 83,175 registered BEVs in January 2019 (KBA 2019)
- Different funding directives by federal ministries of Germany
  - Demonstrate the suitability of BEVs for everyday commercial use
- Commercially used vehicles represents a great potential
  - Early adopters
  - New registrations
  - Driving characteristics

Integration of charging in commercial use

- Conflict of interest in commercial use
  - Periods of non-usability due to stationary charging
  - Restricted availability to provide mileage
- Planning of economic activities depending on the current state of charge
  - Spatial locations of trip destinations and charging opportunities
  - Charging periods during or outside the usual operating hours
  - Remaining range and required daily mileage

Aim of the study

Analysis of the charging behaviour of organisations,
which already use BEVs in commercial transport, to deduce conclusions
on the feasibility of integrating charging into the daily routine

Approach

Collecting spatial, energy- and time-related data
of driving and charging activities with logging devices in BEVs

Data basis: Hamburg – Wirtschaft am Strom

- Funded by the German Federal Ministry of Transport and Digital Infrastructure between 2012 and 2017
- Focus on BEV < 3.5 t in commercial transport
- Organisations from the Hamburg metropolitan area

- 740 funded BEVs
- 367 different organisations
- 18 of 21 economic sectors

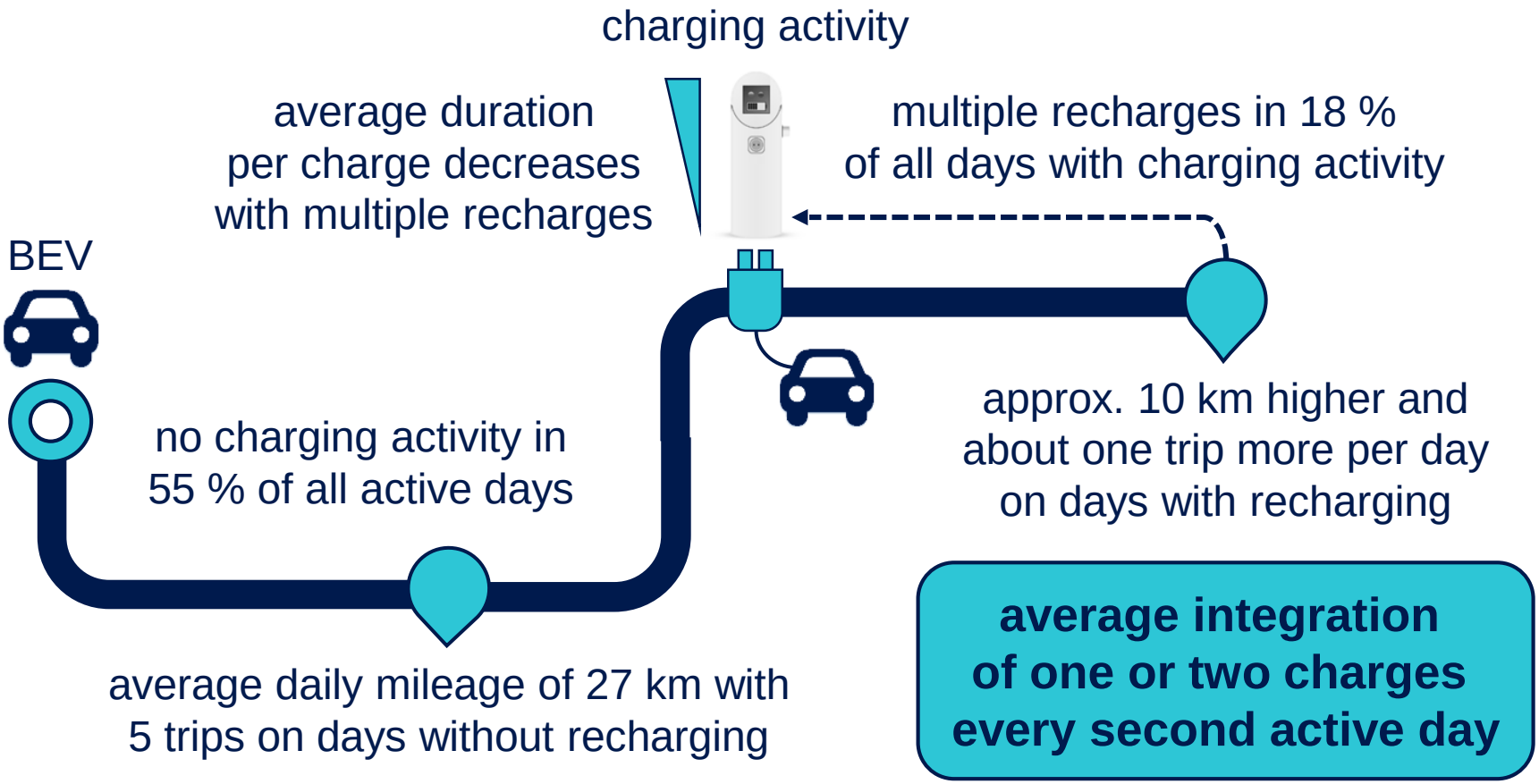
- 160 sampled BEVs
- 5 vehicle models
- Different fleet sizes
- 45,828 active days

- 254,061 trips
- approx. 1.5 million km

- 26,131 charges
- 176,000 kilowatt hours

Average driving and charging activity of the BEVs

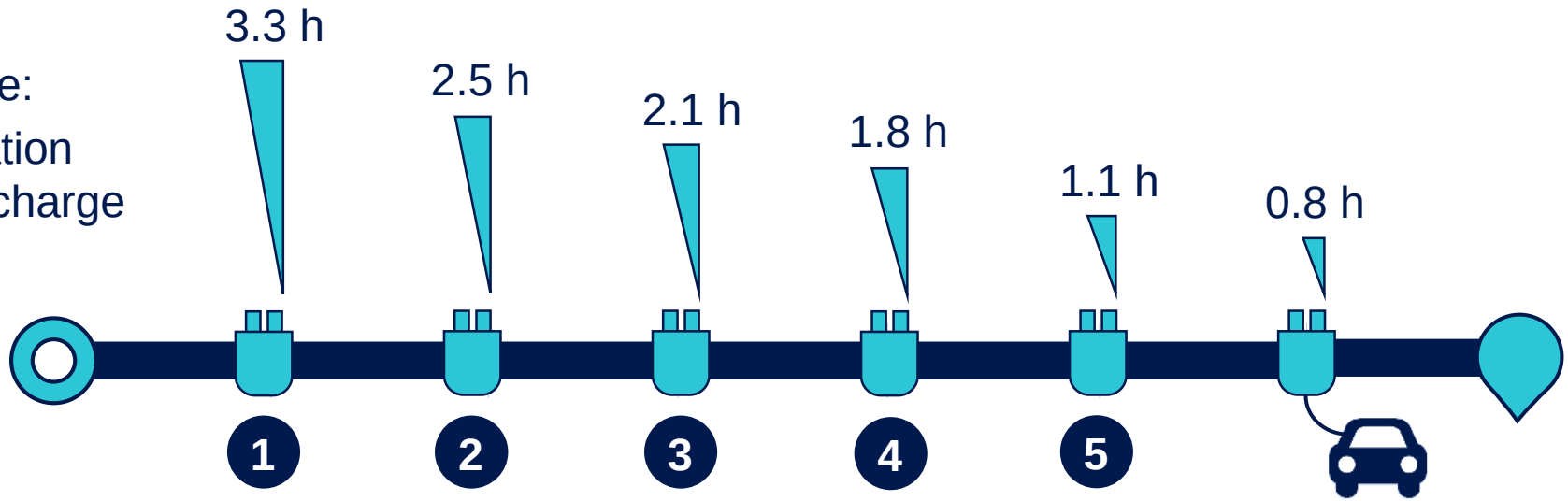
- Commercial vehicles with internal combustion engines (ICEV) in Hamburg drive 65.5 km by an average of 3.2 trips per day (Wermuth et al. 2012)



(n = 160 BEV; 26,131 charges; 254,061 trips; 45,828 active days)

Multiple recharging per day

- Effect of multiple recharging on the daily mileage

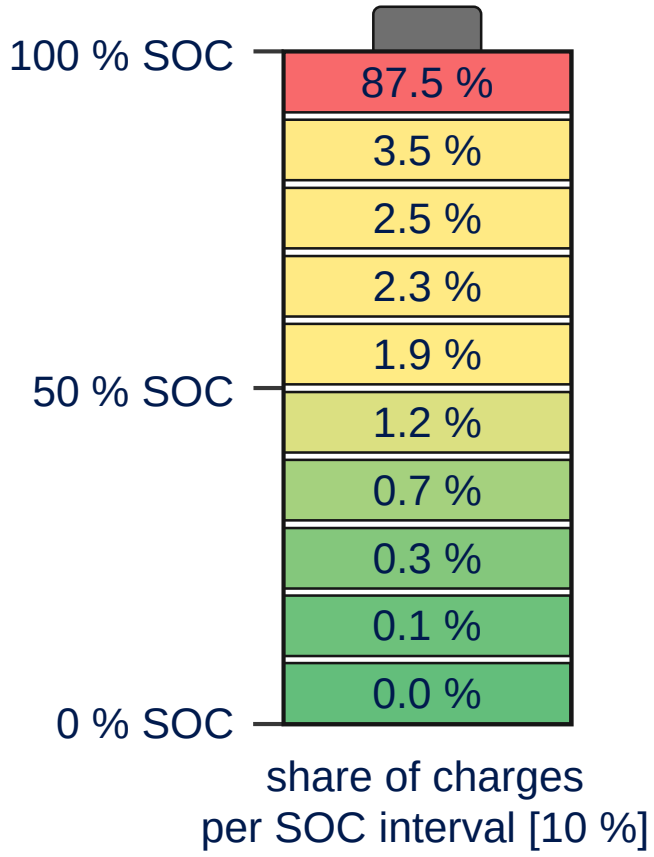


	1	2	3	4	5	
daily mileage	34 km	52 km	68 km	72 km	158 km	350 km
trips per day	6 trips	7 trips	8 trips	9 trips	8 trips	7 trips

Higher daily mileages by integration of multiple shorter recharges

(n = days)	(n = 16,826)	(n = 3,333)	(n = 438)	(n = 71)	(n = 14)	(n = 4)

Final state of charge

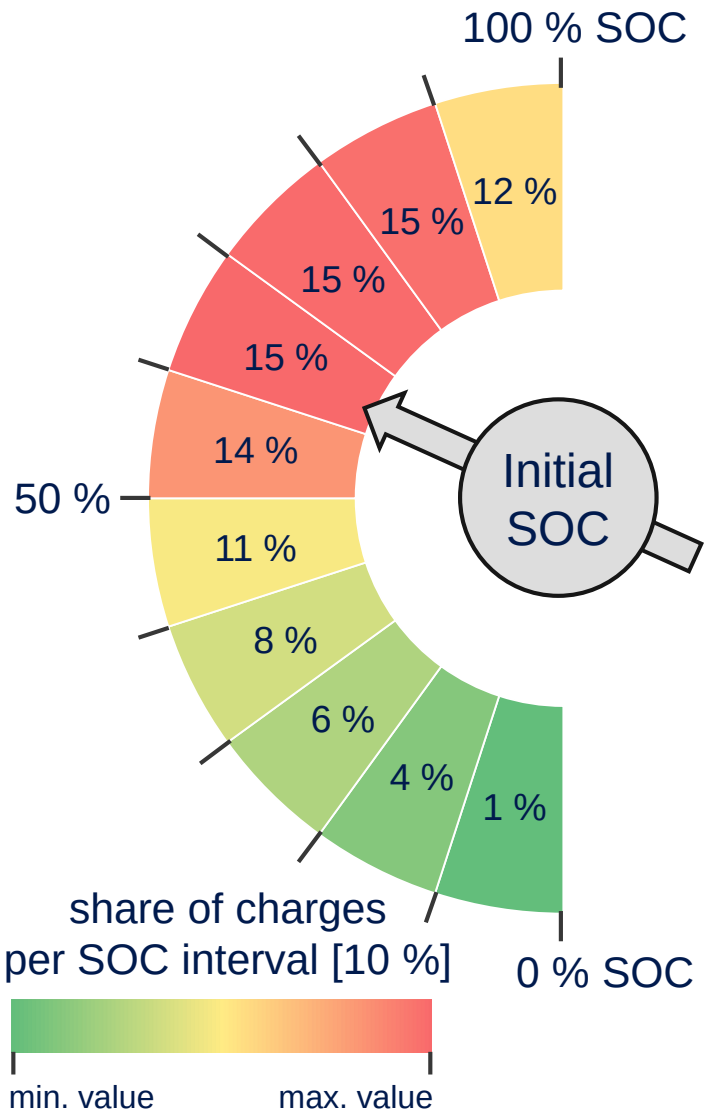


- Full charging (above 90 % SOC) is common
  - Regardless of the initial SOC
- Intermediate charging is rare
  - Higher necessity to pursue the commercial transport activities

Predominant charging behaviour is to fully recharge the BEV

(n = 160 BEV; 26,131 charges)

Initial state of charge



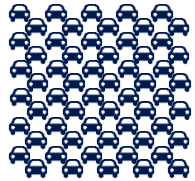
(n = 160 BEV; 26,131 charges)

- One reason for the high amount of full charges is the overall high initial SOC
- Average initial state of charge: 62 % SOC (Flämig et al. 2017)
- The necessity of recharging due to a low-level SOC was avoided
- Contradicts the usual understanding for initiating charges

Preventive charging behaviour to keep a high state of charge

Fleet sizes

- Interdependency of the preventive charging behaviour with the fleet size

	micro fleets (1 V)	small fleets (2 to 5 V)	medium fleets (5 to 49 V)	large fleets (> 50 V)
Proportion in the sample	 10 %	 34 %	 36 %	 19 %
Average proportion of BEVs in the fleet	100 %	42 %	14 %	5 %
Average initial SOC	62 %	56 %	68 %	62 %

Limited dependency of the preventive charging behaviour with the fleet size

Temporal charging behaviour

time of day	00:00 - 01:59	02:00 - 03:59	04:00 - 05:59	06:00 - 07:59	08:00 - 09:59	10:00 - 11:59	12:00 - 13:59	14:00 - 15:59	16:00 - 17:59	18:00 - 19:59	20:00 - 21:59	22:00 - 23:59	∑ %	
∑ %	1	1	2	6	11	14	16	15	13	10	7	3	100	**duration**
percentage of charging processes [%]	0	0	0	1	2	4	4	3	2	1	1	0	20	< 1 hour
	0	0	1	2	2	4	4	3	2	1	1	0	22	1 - 2 hours
	0	0	0	1	2	3	3	3	2	1	1	1	17	2 - 3 hours
	0	0	0	1	1	1	2	2	2	1	1	0	14	3 - 4 hours
	0	0	0	1	1	1	1	1	2	1	1	0	10	4 - 5 hours
	0	0	0	0	1	1	1	1	1	1	1	0	7	5 - 6 hours
	0	0	0	0	0	0	0	0	1	1	1	0	4	6 - 7 hours
	0	0	0	0	0	0	0	0	0	1	0	0	3	7 - 8 hours
	0	0	0	0	0	0	0	0	0	0	0	0	2	8 - 9 hours
	0	0	0	0	0	0	0	0	0	0	0	0	2	> 9 hours

- Organisations tend towards short or medium charging durations
- Long durations are postponed to the end of the usual operating hours

(n = 160 BEV; 26,131 charges)

Charging within the usual operating hours is feasible

Conclusion

- Lower daily mileage than comparable commercially used ICEVs
  - Reached the same level by an increasing number of recharges per day
- Preventive charging behaviour is predominant
  - Plugged-in regardless of the initial state of charge
  - Necessity due to a low level state of charge was avoided
- Temporal preferences within the operating hours are identified
  - Charging is feasible with different approaches
- BEVs can be suitability for everyday commercial use
- Potential to increase the number of vehicles in commercial fleets
- Limitations: No comparison within the commercial fleet of the organisation; Re-adjustment with appropriate scaling of electrical fleets
- Further research: Combination with an analysis of driving behaviour; Spatial evaluation of the intermediate charging

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Thank you for your attention!

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Initial and final state of charge

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	final SOC	90 - 100 % SOC	80 - 90 % SOC	70 - 80 % SOC	60 - 70 % SOC	50 - 60 % SOC	40 - 50 % SOC	30 - 40 % SOC	20 - 30 % SOC	10 - 20 % SOC	< 10 % SOC	∑ %	state of charge - SOC
∑ %	87,5 %	3,5 %	2,5 %	2,3 %	1,9 %	1,2 %	0,7 %	0,3 %	0,1 %	0,0 %		100%	**initial SOC**
number of charging processes (n = 26,131)	3.036											11,6 %	90 - 100 % SOC
	3.760	99										14,8 %	80 - 90 % SOC
	3.648	175	69									14,9 %	70 - 80 % SOC
	3.430	172	171	132								14,9 %	60 - 70 % SOC
	2.932	158	129	197	161							13,7 %	50 - 60 % SOC
	2.202	126	108	114	162	102						10,8 %	40 - 50 % SOC
	1.681	95	80	78	80	107	61					8,4 %	30 - 40 % SOC
	1.210	55	51	48	59	73	70	39				6,1 %	20 - 30 % SOC
	713	21	26	19	31	24	28	39	15			3,5 %	10 - 20 % SOC
	247	13	7	14	6	10	16	13	16	3		1,3 %	0 - 10 % SOC

Temporal charging behaviour

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time of day	00:00 - 01:59	02:00 - 03:59	04:00 - 05:59	06:00 - 07:59	08:00 - 09:59	10:00 - 11:59	12:00 - 13:59	14:00 - 15:59	16:00 - 17:59	18:00 - 19:59	20:00 - 21:59	22:00 - 23:59	∑ %	
∑ %	1,0 %	0,9 %	1,8 %	6,2 %	11,3 %	13,9 %	16,3 %	15,3 %	13,1 %	10,1 %	6,8 %	3,3 %	100 %	duration
percentage of charging processes (n = 26,131)	0,2 %	0,2 %	0,2 %	1,3 %	2,4 %	3,9 %	3,8 %	3,3 %	2,3 %	1,3 %	0,7 %	0,4 %	20,0 %	< 1 hour
	0,2 %	0,2 %	0,7 %	1,6 %	2,3 %	4,1 %	4,1 %	3,4 %	2,5 %	1,3 %	0,9 %	0,4 %	21,9 %	1 - 2 hours
	0,2 %	0,2 %	0,4 %	1,1 %	2,1 %	2,6 %	3,1 %	2,9 %	1,9 %	1,4 %	1,1 %	0,6 %	17,5 %	2 - 3 hours
	0,2 %	0,1 %	0,3 %	1,0 %	1,4 %	1,3 %	2,5 %	2,1 %	1,7 %	1,4 %	1,4 %	0,4 %	13,9 %	3 - 4 hours
	0,1 %	0,1 %	0,1 %	0,5 %	1,2 %	0,8 %	1,3 %	1,5 %	1,7 %	1,4 %	0,8 %	0,4 %	10,0 %	4 - 5 hours
	0,1 %	0,0 %	0,0 %	0,2 %	0,8 %	0,6 %	0,6 %	0,9 %	1,2 %	1,2 %	0,5 %	0,3 %	6,7 %	5 - 6 hours
	0,0 %	0,0 %	0,0 %	0,1 %	0,4 %	0,2 %	0,3 %	0,4 %	0,7 %	0,8 %	0,5 %	0,3 %	3,7 %	6 - 7 hours
	0,0 %	0,0 %	0,0 %	0,1 %	0,2 %	0,1 %	0,2 %	0,3 %	0,4 %	0,6 %	0,5 %	0,2 %	2,7 %	7 - 8 hours
	0,0 %	0,0 %	0,0 %	0,1 %	0,2 %	0,1 %	0,2 %	0,2 %	0,3 %	0,3 %	0,2 %	0,1 %	1,6 %	8 - 9 hours
	0,0 %	0,0 %	0,0 %	0,1 %	0,1 %	0,1 %	0,2 %	0,3 %	0,3 %	0,4 %	0,3 %	0,1 %	2,0 %	> 9 hours