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# INNOVATION AND INFRASTRUCTURE – THE CASE OF ELECTRIC VEHICLES IN GERMANY

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# Eliciting change in the mobility sector

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- **Electric vehicles** can be considered an innovative means of motorised individual mobility:
    - reducing global CO<sub>2</sub>-emissions by combining EVs with renewable energy sources
    - decreasing local traffic noise and local emissions
    - requiring frequent recharging to overcome limited range
  - This **innovation** seems to depend strongly on charging options, i.e. **infrastructure**
    - Public and semi-public charging options to overcome limited range
  - **Problem:** road-infrastructure already available for motorised vehicle but not public electricity charging infrastructure
- Which **infrastructure is necessary** to successfully promote electric vehicles?
- ...from a *technical* perspective
  - ...from an *economical* perspective
  - ...from a *psychological* perspective
  - And what recommendations can be derived by combining the three of them?

# Electric vehicles and charging options

## Characterisation of vehicle types

Property	Gasoline vehicle	Electric vehicles	
		Plug-in-Hybrid	Battery electric vehicle
Range	> 700 km	50 + 600 km	< 150 km
Refueling Frequency	Every 2 weeks	When necessary + every day	Every 3 days or 30% every day
Refueling Duration	3 minutes	3 minutes + 2 hours	0.5 - 8 hours

## Overview of Different Charging Concepts

Charging Infrastructure	Conductive (cable-charging)	Inductive charging	Battery swap
 <b>Private Connection</b>	60% of all German drivers	<ul style="list-style-type: none"> <li>Very comfortable</li> <li>Rather expensive</li> </ul>	<ul style="list-style-type: none"> <li>Far too expensive</li> </ul>
 <b>Semi-public Connection</b>	<ul style="list-style-type: none"> <li>At work</li> <li>Easy to install</li> </ul>	<ul style="list-style-type: none"> <li>Very comfortable</li> <li>Rather expensive</li> </ul>	<ul style="list-style-type: none"> <li>Unlikely</li> </ul>
 <b>Public Charging Point</b>	<ul style="list-style-type: none"> <li>Relevant for &lt;11% of all German drivers</li> </ul>		

Quelle: eigene Darstellung

# Costs for different charging options

Infrastructure	Billing	Maximal power	Costs in addition to electricity (in c€/kWh)		
			cable	inductive	Battery swap
Private	No	3,7 kW	1 – 2	17 – 38	
		11 - 22 kW	2 – 5	26 – 56	
Semi-public	Yes	11 - 22 kW	4 – 13	21 – 42	
	No		4 – 11	29 – 59	
public	Yes	11 - 22 kW	9 – 34	43 – 95	8 – 12
	Yes	43 kW	5 – 19		
		100 kW (DC)	10 – 21		
			+ cheap – Need to plug in – Vandalism possible	+ Easy to use + For niches? – expensive – No standards yet	+ Very fast – expensive – Battery size standards required

Note: 4.300 km/a, consumption 16 kWh/100km,  
Source: Fabian Kley (2011), Schraven et al. (2011)



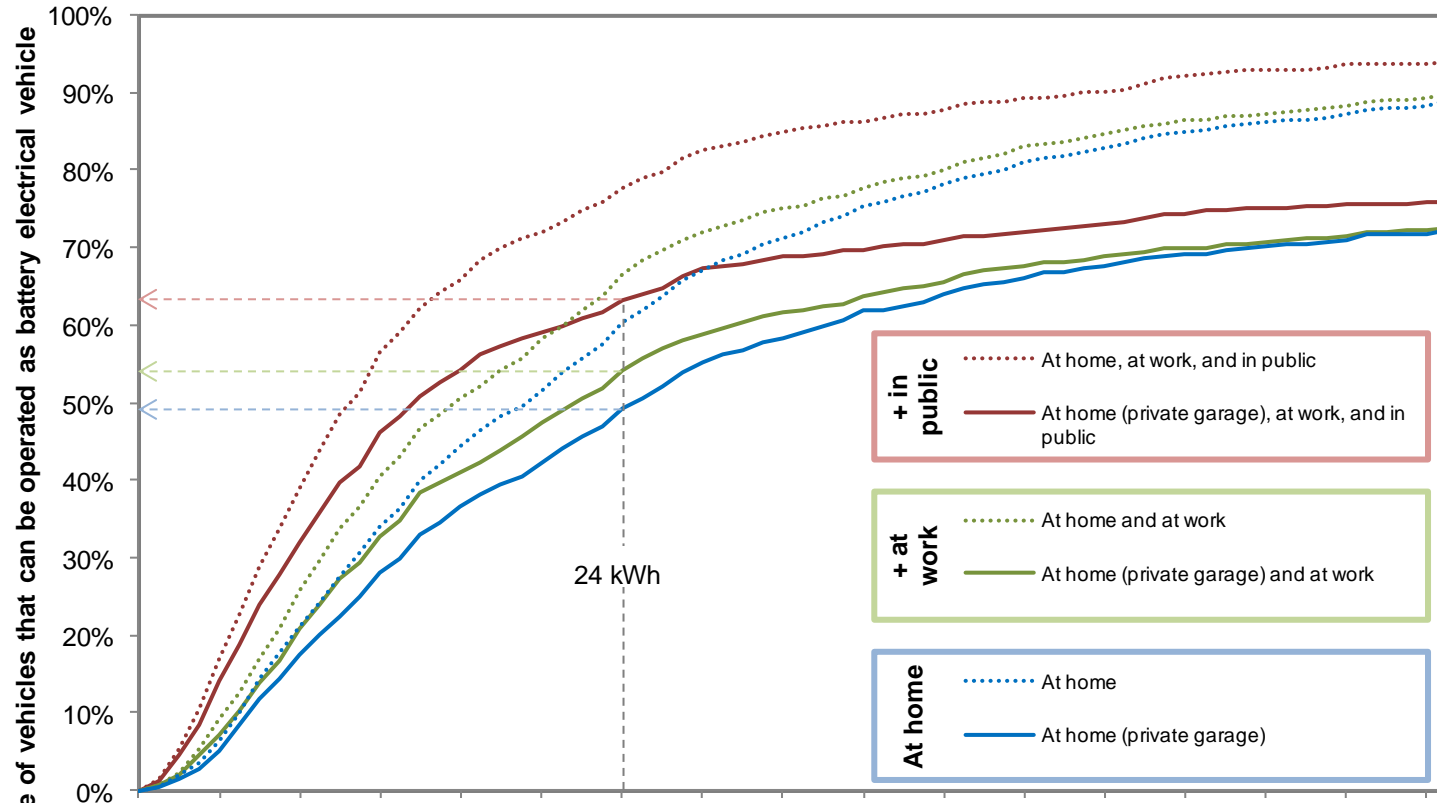
Cable home charging is the only inexpensive option.

# Data and assumptions for technical charging infrastructure need

- Driving behaviour from German Mobility Panel [MOP (2008)]
  - German movement profiles for representative week one week
  - 1994-2008: 12,812 households
  - Allocation to cars where possible reduces sample to 6,629 car-specific driving profiles
- Simulation of battery profiles with main assumptions:
  - Uncontrolled charging whenever possible
  - All cars medium-sized with consumption 0.194 kWh/km [Helms and Hanusch (2011)]
  - in different infrastructure scenarios (table below) [Kley (2011)]

power rates [kW]	private	semipublic	public
home-only (IS <sub>a</sub> )	3.7	-	-
home-and-semipublic (IS <sub>b</sub> )	3.7	11.1	-
everywhere (IS <sub>a</sub> )	3.7	11.1	11.1

# Influence of charging infrastructure on battery electric vehicles (**BEV**)

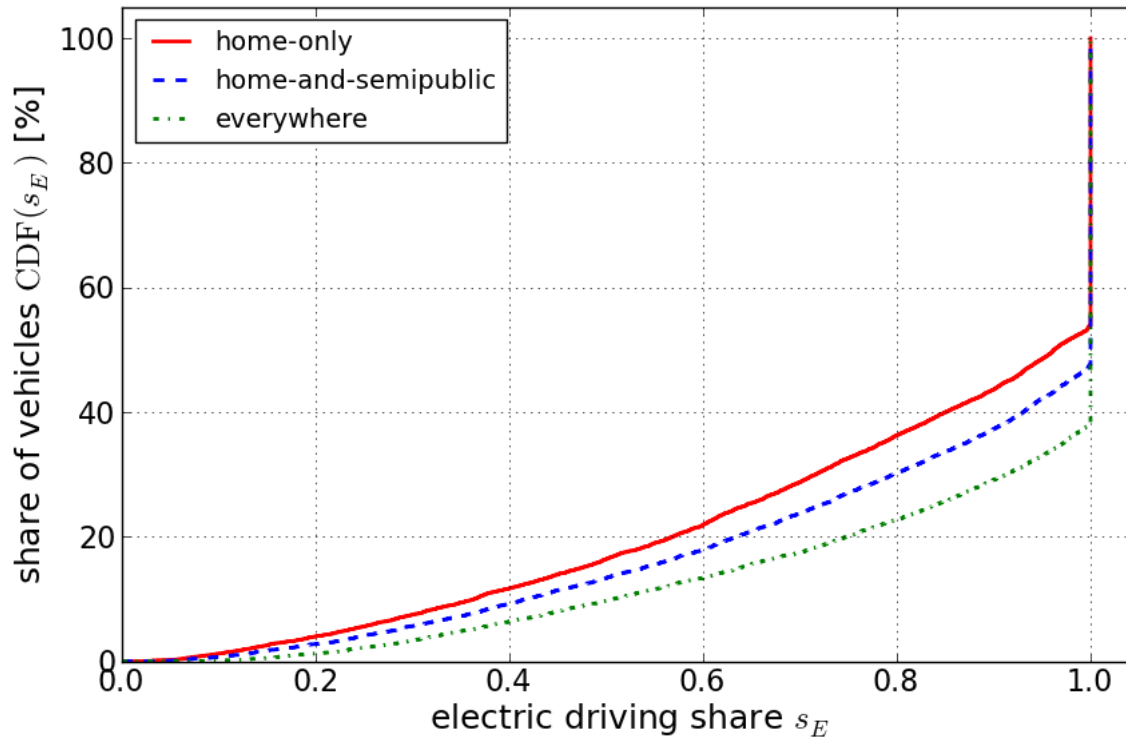


- **~60% of cars** can be charged **privately**
- With the restriction of accessible private parking spaces, ~50% of today's cars can be an EV (20 Mill. In GER)
- Additional charging stations at work increases this share to 65%
- Further public charging yields 80%



Large share of battery electric vehicles with home-charging possible and little change by ubiquitous infrastructure

# Influence of charging infrastructure on electric driving share of **Plug-in-hybrids**



- PHEV with 10 kWh (net) battery ~ Opel Ampera
- 50% of drivers go all-electric
- 60% of drivers drive more than 80% electrically
- Small change by additional infrastructure



Plug-in-hybrids offer large electric driving shares even without additional public infrastructure

# Survey Data for psychological analysis

- 8 Pilot Regions for electric mobility in Germany

*T0 before vehicle delivery:*  
What are the consumers  
expecting regarding electric  
mobility?  
N=835

*T1 First impressions  
(after 1-11 weeks of usage)*  
What are initial impressions  
of using an electric vehicle?  
N=781

*T2 adapting to E-mobility  
(after several months of  
usage):*  
How do consumers perceive E-  
mobility in everyday use?  
N=690

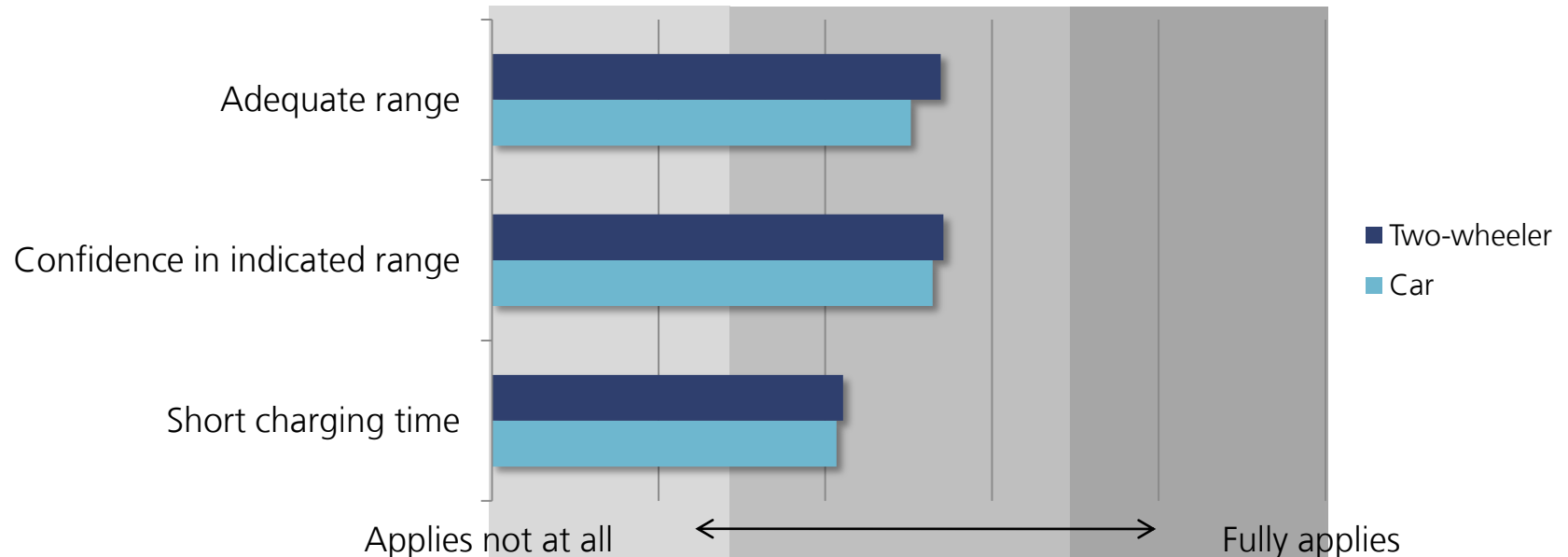


- N = 2306
- Used vehicles: 50% cars, 42% two-wheelers, 5% transporters (T1)
- 45% predominantly private use, 36% predominantly commercial use, 19% private and commercial use
- Sample description:
  - > 75% male participants
  - Mean age: ~ 40 years
  - On average good education: ~ 65% with university-entrance diploma



# Results on user needs and user behaviour from a psychological perspective

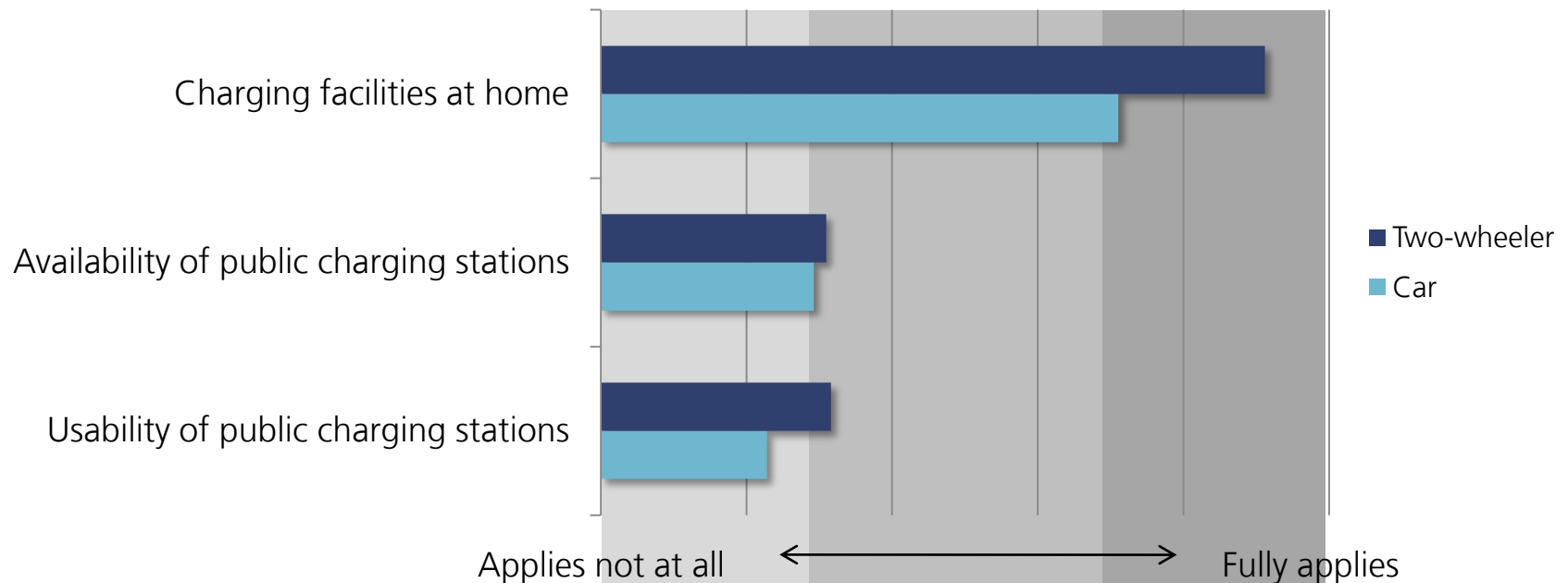
- Range and charging time from a user's point of view still critical (T1 survey):
  - Range itself as well as trust in indicated range are not sufficient
  - Uncertainty in handling restricted range. No differences between users of cars and two-wheeled vehicles
- Range and charging time evaluated even worse by long term users (T2 survey):  
*"Are the following aspects of EVs sufficient for every-day use?"*



# Results on user needs and user behaviour from a psychological perspective

- Thus charging facilities are important for the users: (T1 survey)
  - At home the majority is well equipped, especially users of two-wheelers
  - But **users wish for more facilities in public places**

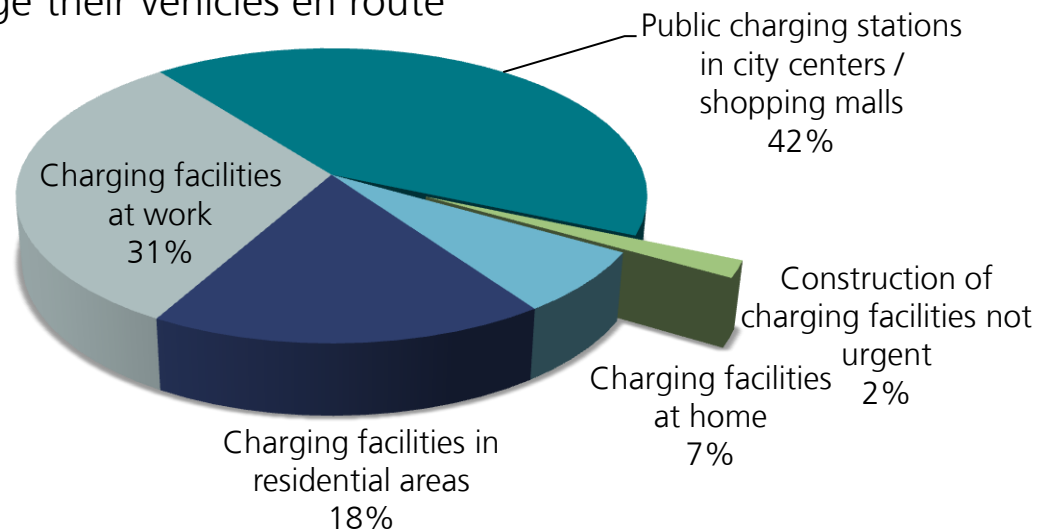
*“Are the following aspects of EVs sufficient for every-day use?”*



# Results on user needs and user behaviour from a psychological perspective

- Where do users wish for charging facilities? (T2 survey)
  - Majority wishes for facilities in city centres
  - User's want to recharge their vehicles en route

*"Where is the need for construction of charging options most urgent?"*



- When asked which measures may promote usage of EVs in Germany, construction of charging facilities is mentioned second most (after subsidies for EV purchase)

# Summary and Conclusion

1

## Technical perspective

- Majority of potential users can easily charge at home (20 mill. EVs technically possible without special infrastructure)
- BEV+PHEV: Additional infrastructure has small but measurable effect
- Plug-in-Hybrids offer solution without expensive infrastructure

2

## Economical perspective

- Public charging infrastructure rather expensive
- Yet no simple business models for charging infrastructure known

3

## Psychological/ acceptance perspective

- Limited range of vehicles is serious drawback for users
- Even experienced users want more public charging infrastructure
- Well-located public charging options necessary for user acceptance

## Infrastructure for Electric vehicles

**Extensive construction of public charging infrastructure is *not* necessary, but some public charging facilities could support the market diffusion of EVs.**