WHAT IS THE FUTURE OF PUBLIC CHARGING INFRASTRUCTURE FOR ELECTRIC VEHICLES? –

A TECHNO-ECONOMIC ASSESSMENT OF PUBLIC CHARGING POINTS FOR GERMANY

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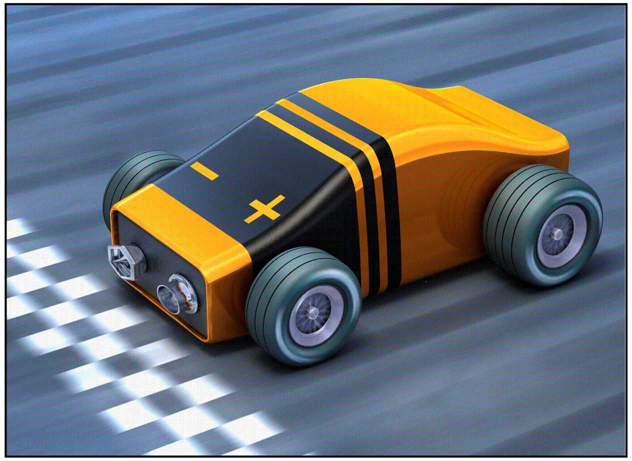
eceee Summer Study, Hyères, France



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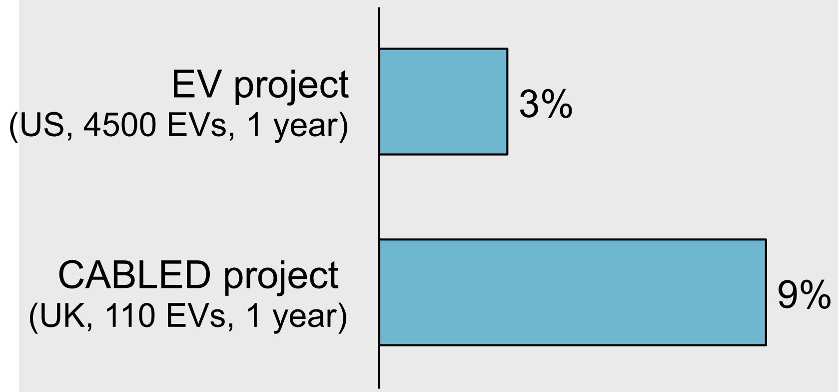
Charging infrastructure is crucial for adoption of electric vehicles.

- **Charging infrastructure is one of the main barriers to EV adoption** ((Dütschke et al., 2012), (Roland Berger, 2013), (EC, 2013))
- **Infrastructure and vehicle adoption are connected**: „simultaneous built-up of charging infrastructure and vehicle penetration“ in Germany (NPE 2012)
- **Public charging infrastructure rarely used** ((EVIX, 2012), (Bruce et al., 2012))

→ **How much public charging infrastructure do we really need for EV market penetration?**

- Lot of work for other alternative fuels, but charging infrastructure for EVs currently not adequately addressed (EC approach rather simple)
- User behaviour rarely addressed explicitly

Public charging by electric vehicles
How much electricity has been charged publicly?



- Public charging options are hardly used
- Similar results are reported for Germany

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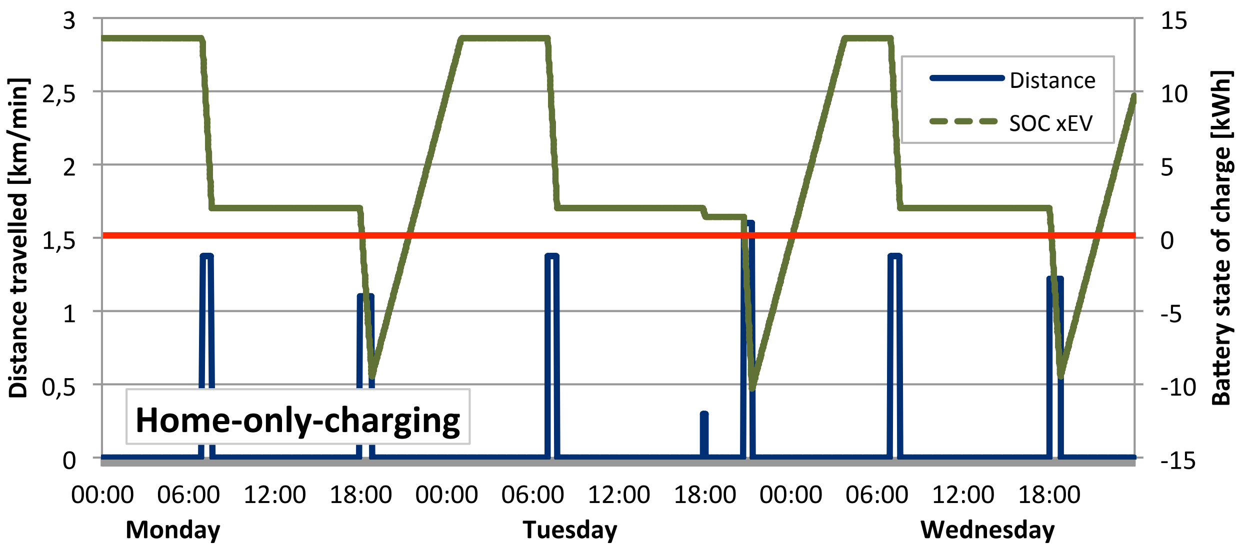
Approach (1/2) – With the driving profile we simulate a battery profile.

Example of a driving profile*

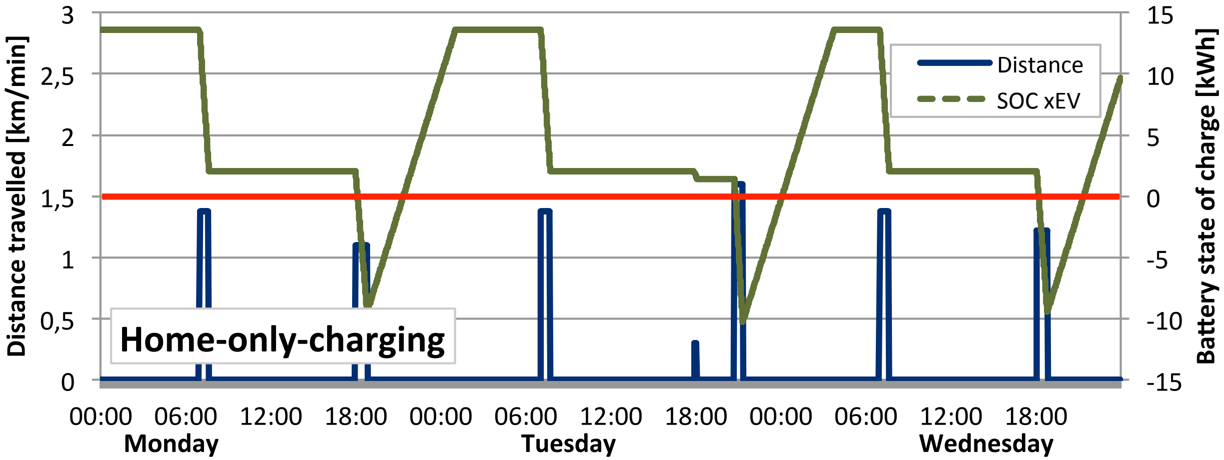
Departure Date	Departure Time	Arrival Date	Arrival Time	Distance [km]	Purpose
2013-03-18	07:00	2013-03-18	07:40	55	Way to work
2013-03-18	18:00	2013-03-18	18:50	55	Way home
2013-03-19	07:05	2013-03-19	07:45	55	Way to Work
2013-03-19	17:55	2013-03-19	18:05	3	To Sports Club
2013-03-19	20:45	2013-03-19	21:20	56	Way home
2013-03-20	07:00	2013-03-20	07:40	55	Way to Work
2013-03-20	18:05	2013-03-20	18:50	55	Way home

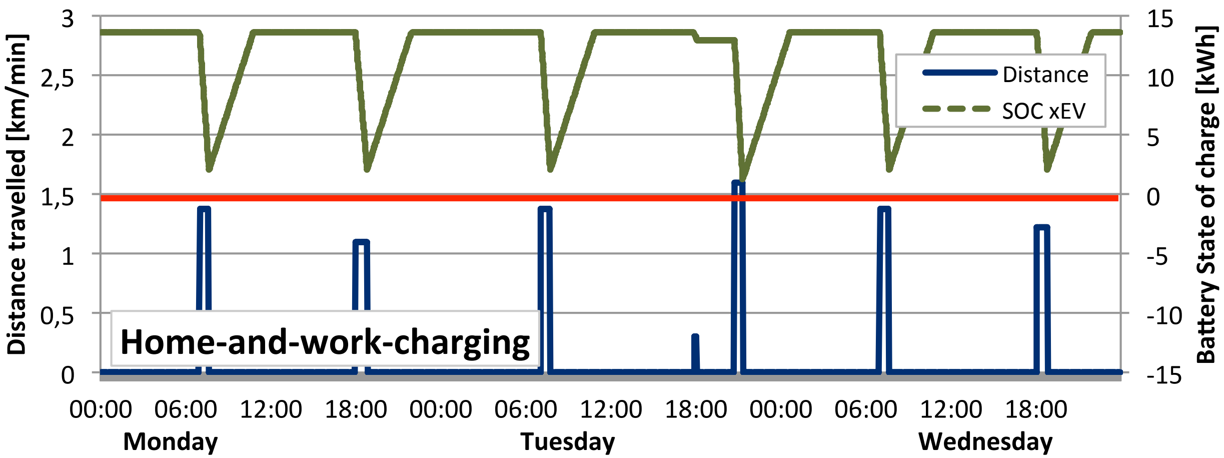


- data set of 6500 driving profiles contain information about driving behaviour of ICEV users
- Simulation of batteries to find
  - technical replaceability by BEVs
  - Electric driving share of PHEV/ REEVs

*fictive driving profile, only for demonstrational purposes

Approach (2/2) – Battery profile depending on charging infrastructure scenario.





Findings in this example:

- BEV not possible with charging only at home
- But possible with charging at work as well

→ Infrastructure may have positive effect

<u>Open question:</u>

- How many **additional users** with more infrastructure?

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With this battery simulation approach we do a threefold analysis.

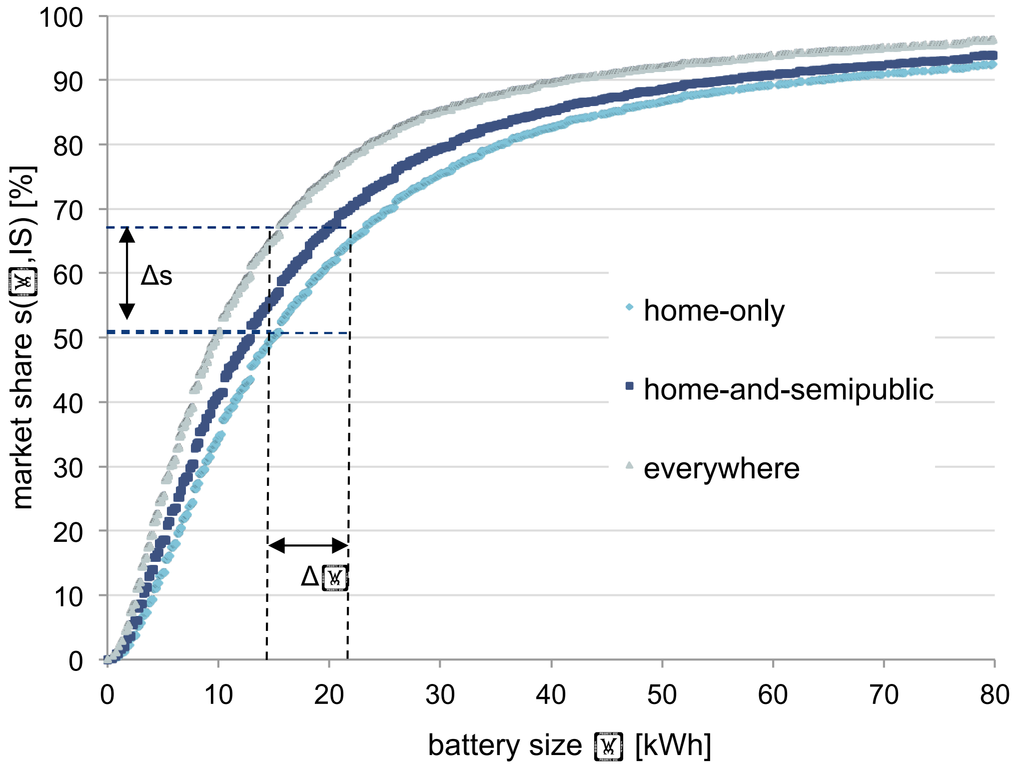
1. **Technical analysis**
    1. Battery profile simulation
    2. All ways possible for BEV?
    3. What electric share for PHEV? *(not shown)*

2. **Macroeconomic analysis**
    1. Every user that is not able to charge at home needs at least one charging point
    2. Distinction who has to bear the cost: All (=tax) or additional (=supplement) users?

3. **Microeconomic analysis**
    1. One charging point per user with distinction of parking
    2. Every user without garage has to pay for public infrastructure

Technical results: Only few additional users through (semi-)public infrastructure.

Share of users that could do all of their driving with a BEV with given battery capacity*



- 50% of all users could do their daily driving with an average battery (16kWh) and home-only-charging.
- Slight increase of user share possible if users could also charge at semipublic locations (+5%)
- Moderate increase if users could charge publicly as well (+15%).

Slight increase with more infrastructure does not justify built-up technically.

<u>Open questions:</u>

- What is more expensive?
- How much public infrastructure is needed?

*Source: Own simulation with data from (MOP, 2010)

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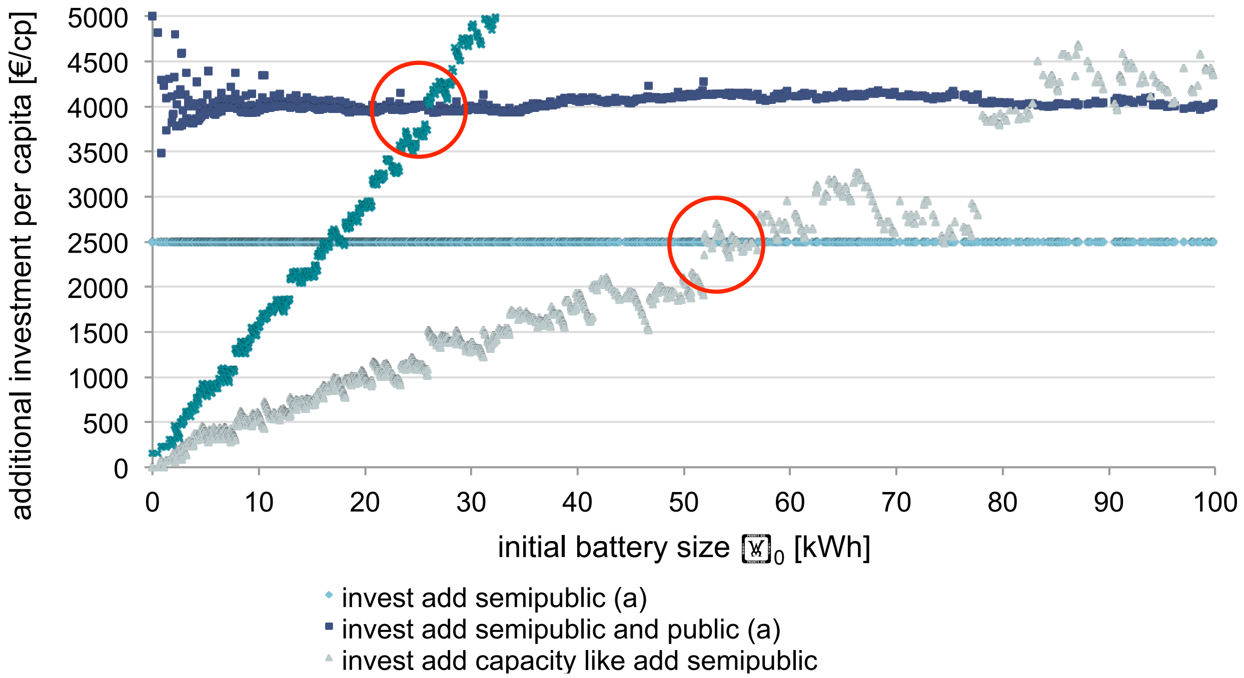
Macroeconomic results: Investment in battery size cheaper for mid-size EV.

Additional investment for battery size and capacity in BEVs*



- Investments per capita under the assumption that every additional user needs one charging point (semipublic or public)
- Investments borne by **additional** users (case a)
- Intersection of additional semipublic charging options compared to increasing battery capacity at around $\boxtimes_0$=50kWh
- For semipublic and public charging options at $\boxtimes_0$=25kWh

Even with high usage assumptions (one charging point per user) no business model, since investment in battery capacity is cheaper.

*Source: Own simulation with data from (MOP, 2010), investments for charging semipublic charging point 2500€ and public charging point 5000€.

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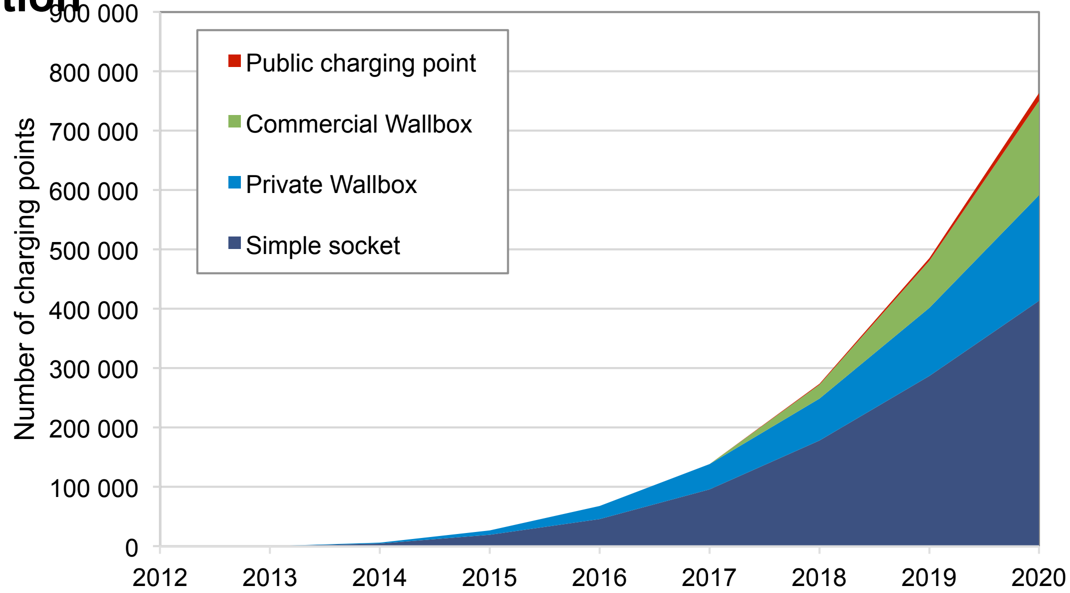
Microeconomic results: Only few users could afford to pay back public charging infrastr.

Number of TCO-optimal EV (BEV&PHEV) users (private& commercial) distinct by primary charging option*



Assumption:

- User has to pay for his car and primary charging point according to his typical parking.

Findings:

- Only few users of public parking lots could bear additional cost of public charging infrastructure.
- Even without those users, significant market shares are possible.

No need to invest in charging infrastructure for early adopters, as they do not need it from an economic perspective.

*Source: Own simulation with data from (infas and DLR, 2002) and (Fraunhofer ISI, 2013) in home-only-charging scenario. Investments for simple sockets 250€, for wallboxes 500€ and for public charging point 3775€, operating cost low and given in paper.

Summary and conclusions up to now

1	**Technical perspective**	▪ Majority of potential users can easily charge at home (20 mill. EVs possible in Germany without public infrastructure) ▪ BEV+PHEV: Additional infrastructure has small but measurable effect ▪ Plug-in-Hybrids offer solution without additional infrastructure
2	**Economical perspective**	▪ Public charging infrastructure very expensive ▪ Yet no business models for charging infrastructure (users may not bear the full cost) ▪ Potential users with garage sufficient to reach significant market share

What is the future of public charging infrastructure for EVs?	**Large-scale built-up of charging infrastructure not necessary (for early adopters) from an economical perspective – some visible charging stations may be helpful psychologically though.**
Methodological Findings	▪ Driving profiles good for user behaviour, but no long-distance trips incl. ▪ Primary charging points good to model, but difficulties with other charging options ▪ Driving profiles for commercial users still insufficient (in Germany)

Questions which arise and further work

Current questions:

- Is charging infrastructure cost for users without garage modelled adequately?
- How can we model/account additional charging infrastructure in (semi-) public places?
- How may we integrate psychological aspects explicitly?
- Is it possible to draw conclusions on fast charging infrastructure?

Next steps:

- Ongoing driving profile collection (commercial drivers)
- Better accounting of infrastructure cost
- Integration of charging infrastructure into vehicle buying decision (min cost → max use) and real stock modelling of charging infrastructure
- Model expansion on FCEVs and their “charging” infrastructure

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Please read our paper for further information.

Thank you for your attention.

References:

Dütschke et al., 2012: Roadmap zur Kundenakzeptanz

Roland Berger, 2013: E-mobility index for Q1 2013

European Comission (EC) 2013: Clean power for transport – Frequently asked questions

Nationale Plattform Elektromobilität (NPE) 2012: Zwischenbericht (Dritter Bericht)

EVIX 2012: Electric Vehicle Survey Panel - A National Study of Consumer Attitudes Toward & Usage of EVs

Bruce et al. 2012: Lessons and Insights from Experience of Electric Vehicles in the Community

MOP, 2010: „Mobilitätspanel Deutschland" 1994-2010.

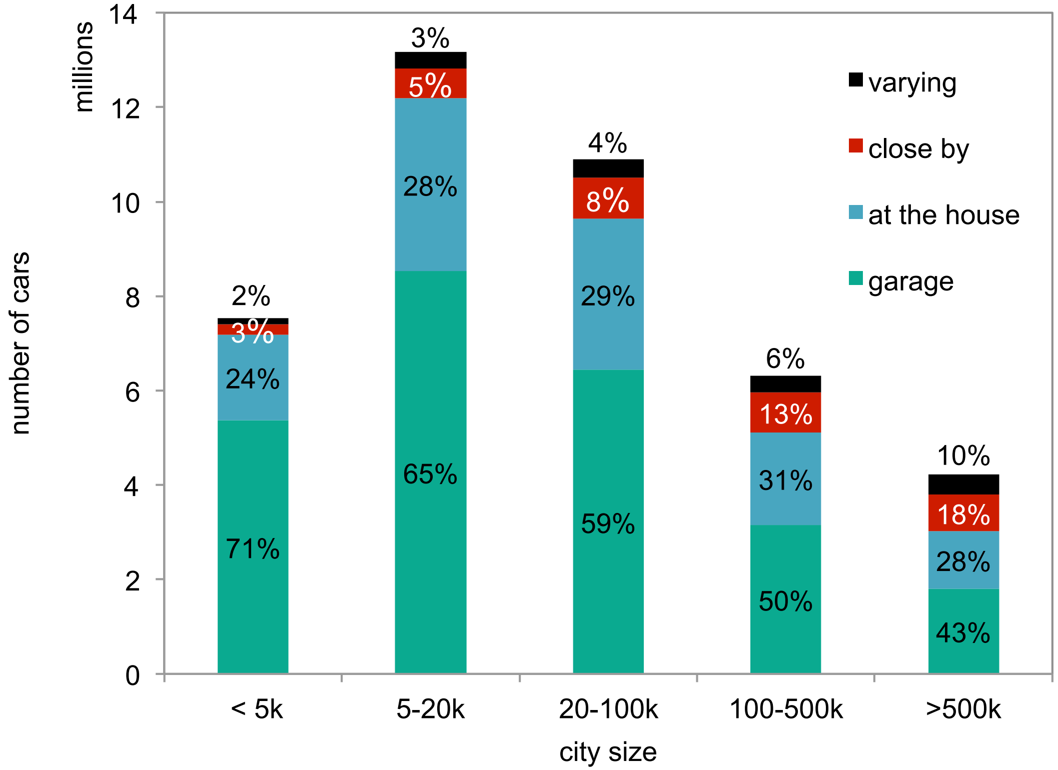
infas and DLR. 2002. Mobilität in Deutschland (MiD) 2002

Fraunhofer ISI 2013: REM2030 Fahrprofile Datenbank

ANNEX

Technical results: Lots of users could easily charge at home.

German passenger vehicle stock subdivided into typical parking spots and city sizes.*



Findings:

- 60% of all users let their car in garages overnight
- Another 30% park their cars close by
- Only 10% of so-called lantern parkers

→ Initial charging infrastructure can be provided rather simple

- **But:** Not sure if all garages do have electricity connection.

*Source: Based on (infas and DLR, 2002) and (KBA 2012)

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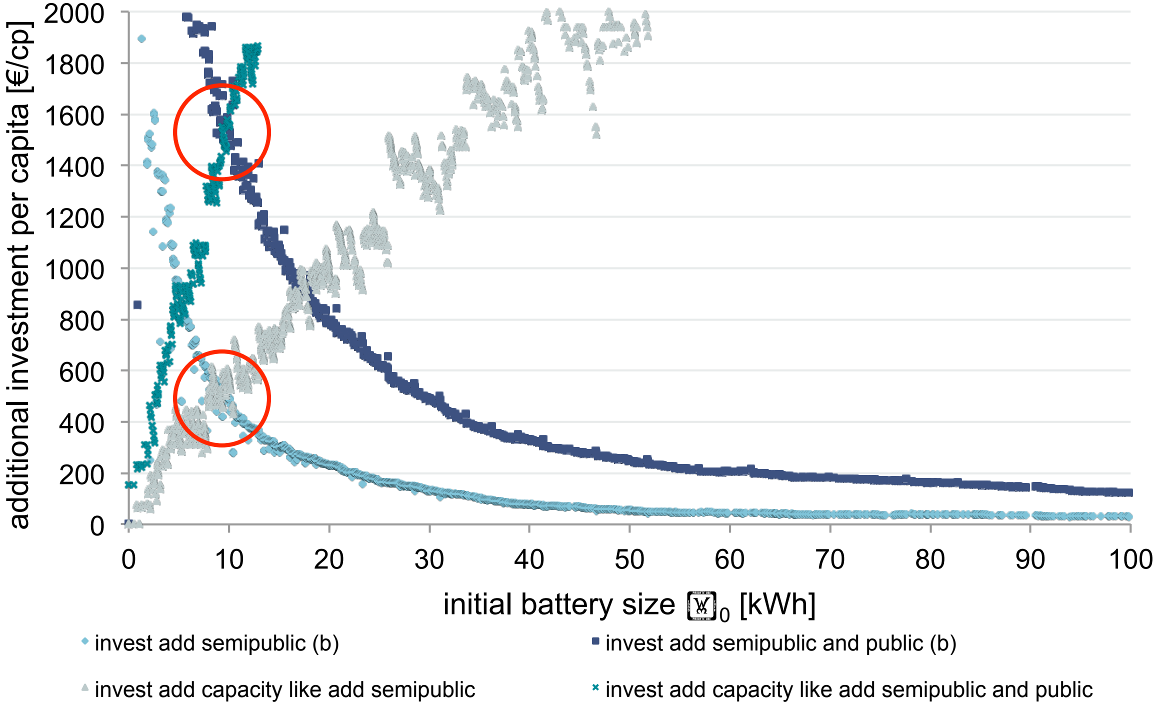
Macroeconomic results: If all BEV-users paid for infrastructure, it would be less expensive than investing in battery size.



- Investments per capita under the assumption that every additional user needs one charging point (semipublic or public)
- Investments borne by **all** users (case b)
- Intersection of additional semipublic charging options compared to increasing battery capacity at around $\square_0$=10kWh
- For semipublic and public charging options at $\square_0$=10kWh

If investment is borne by all users, it may have positive effects.
BUT: Is one point per user sufficient?

*Source: Own simulation with data from (MOP, 2011)

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Electric vehicles and their charging options

Characterisation of vehicle types

		Electric vehicles	
Property	**Gasoline vehicle**	**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
Private Connection	▪ Available in many … cheap	▪ Very comfortable ▪ Rather expensive	▪ Far too expensive
Semi-public Connection	▪ At work ▪ Easy to install	▪ Very comfortable ▪ Rather expensive	▪ Unlikely
Public Charging Point		▪ Too slow … possible)	

How many drivers?

Is this group really relevant for Germany?

Source: Own illustration.

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