Charged up?

Preferences for Electric Vehicle Charging and Implications for Charging Infrastructure Planning

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FCN | Future Energy Consumer Needs and Behavior

E.ON Energy Research Center

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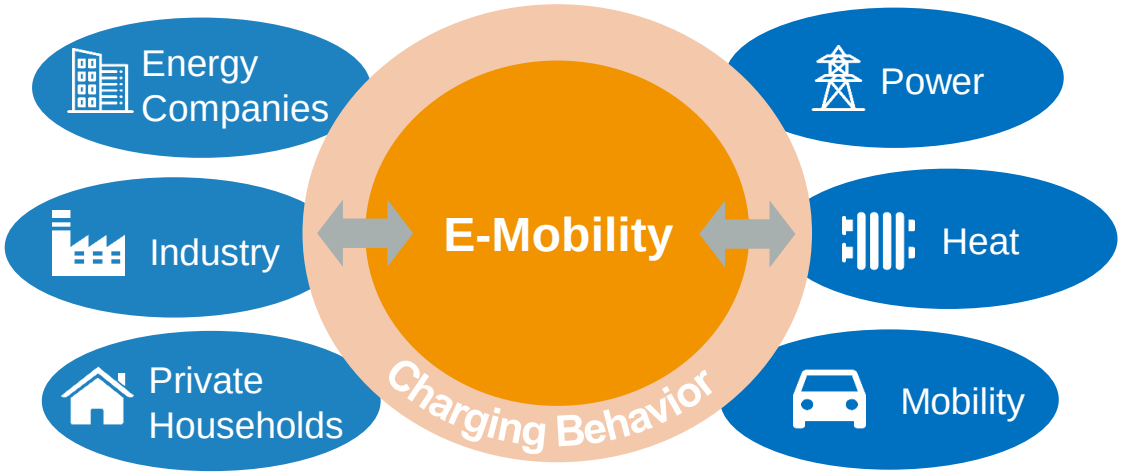
1. Motivation
E-Mobility as a focal point between energy and mobility transitions



Energy transition

- Reduce fossil fuel dependency and CO_2 emissions
- Smart home integration

Charging behavior

- Charging preferences of (future) consumer groups

Mobility transition

- Electric mobility driving and charging behavior

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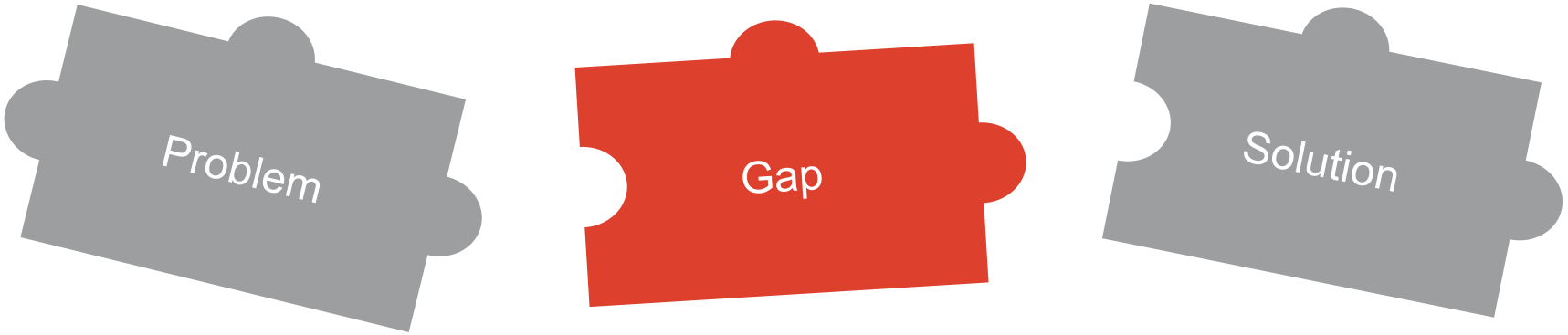
1. Motivation
Research Gap



EV charging infrastructure investments are high & income streams are low (Ito et al. 2013)

- Who is responsible? Car manufacturers, state, municipalities, energy companies? → Business case still missing

Offering charging solutions

- Necessary to understand preferences of current and potential future EV drivers

Some literature on single attributes of the charging process

- Assessment of EV drivers' willingness to pay for different attributes of charging process (charging speed, location, and price; Hackbarth & Madlener 2013, 2016; Hidrue et al. 2011; Tanaka et al. 2014)

Gap

- Charging behavior as a whole bundle including related services

What kind of charging behavior is to be expected in a more mature EV market?

- Sample size too small for field experiment → online experiment

Discrete choice experiment

- Measuring preferences for attributes indirectly by confronting respondents with hypothetical choice bundles
- Targeting potential EV customers

Introduction to respondents

“Assume that you regularly drive and charge an e-car. The range of the e-car is sufficient for your daily driving needs. Please imagine how and where you would like to charge the e-car’s battery. Please assume that the two options are identical in all aspects not mentioned here, i.e. assume a generic e-car that is identical with respect to size, range, motor power etc.“

Example of a Choice Card (full range of attributes). Repeated 12 times for each respondent.

ATTRIBUTES	LEVELS	
Place of charging	At home	At work
Charging duration (full charge)	10 min	4 hours
Charging technology	Tethered charging (with cable)	Inductive charging (without cable)
Waiting time for available charging station	0 min	30 min
Share of renewables	50 %	25 %
Charging cost per month	200 €	100 €
	○ **OPTION A**	○ **OPTION B**

CHOICE

2. Methodology
Discrete Choice Experiment

- The number of both attributes and levels is limited so that respondents are not overburdened
- The design algorithm ensures that all levels appear on the same number of choice cards
- Individuals maximize their utility by choosing a particular charging solution
- Respondents are forced to consider tradeoffs between the attributes that define the two options A and B

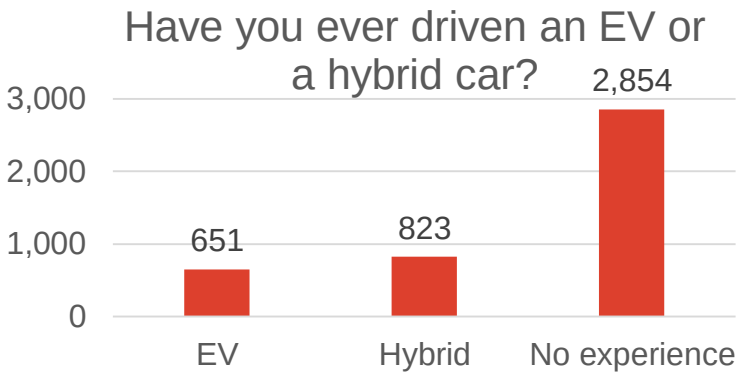
Overview of Attribute Levels				
Place of charging	At home	At work	Roadside: Primary	Roadside: Secondary
Charging duration (full charge)	10 min	30 min	4 hours	8 hours
Charging technology	Tethered charging (with cable)		Inductive charging (without cable)	
Waiting time for available charging station	0 min	5 min	10 min	30 min
Share of renewables	25 %	50 %	75 %	100 %
Charging cost per month	50 €	100 €	150 €	200 €

ATTRIBUTES

LEVELS

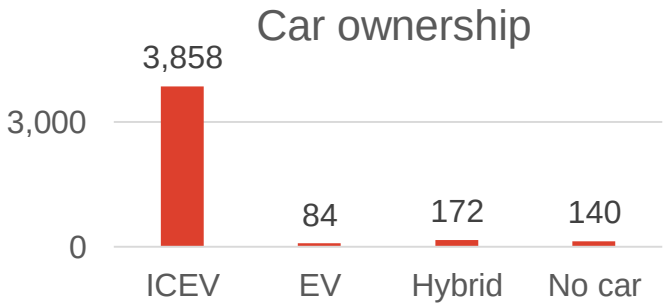
2. Methodology
Discrete Choice Experiment and survey

- Representative sample, *N* = 4.101
- Restriction: drivers‘ license holders <= 75 years
  - = 47 % females
  - = 19-72 years (mean 49.48)
  - = 37 km daily driving distance (mean)
  - = 58% home owners, 42% tenants



- 50% EV experts (screening questions)

- Questionnaire
  - = Standard demographics
  - = Car usage and parking situation
  - = Preference order of charging location and of payment scheme
  - = Environmental consciousness regarding mobility
  - = Control questions



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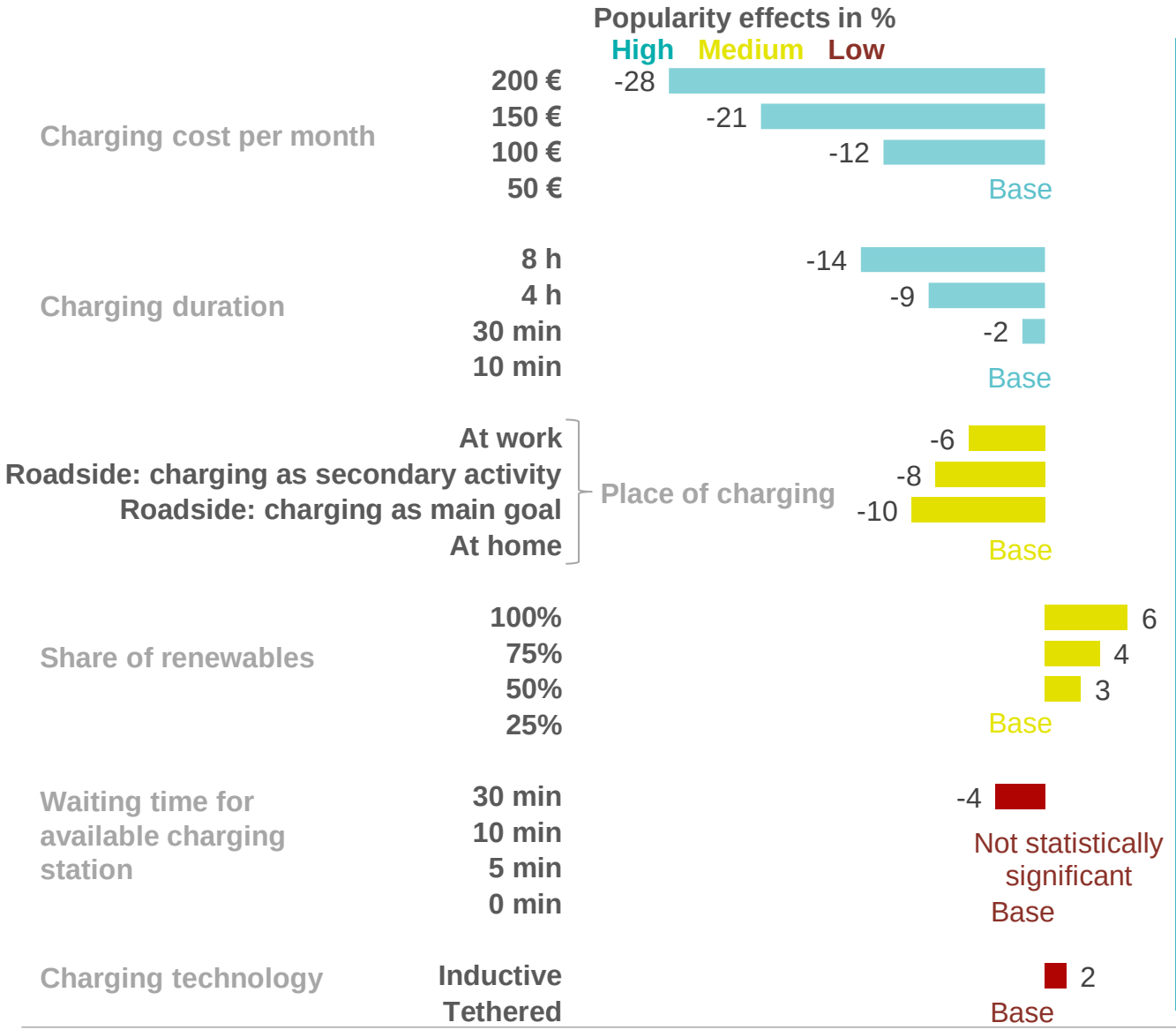
3. Results
Marginal effects



On average, a choice set with cost of €200 is selected 28% less often compared to a choice set with cost of €50.

Hardly any difference between 10 and 30 min of charging duration.

At-home-charging preferred to charging at work or roadside.

Higher share of renewables preferred.

30 min of waiting time are more relevant than 30 min of charging duration.

Weak preference for inductive charging.

3. Results
Willingness to Pay (WTP)

Variable	WTP (€/month)
Charging duration (reduction of 1 min)	0.16
Waiting Time (reduction of 1 min)	0.82
Renewable share (increase by 1%)	0.42
Technology (inductive instead of cable)	8.38

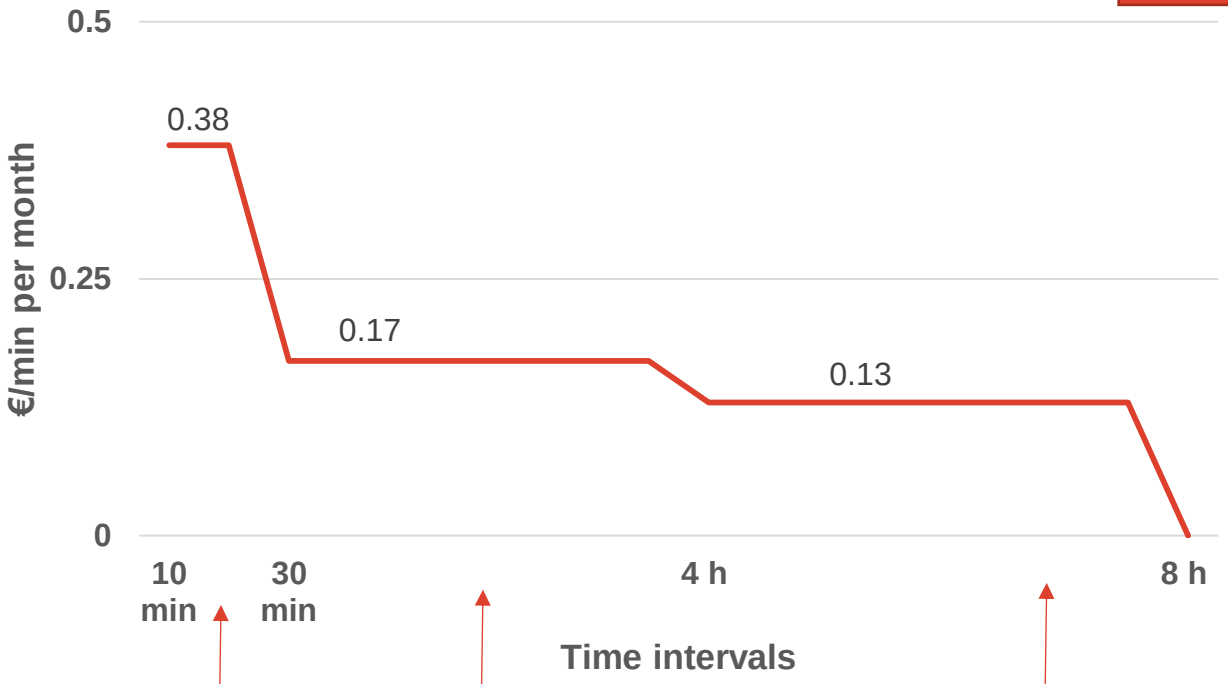
Charging location	WTP (€/month)
At home	(base)
On the road main	-46.26
On the road side	-35.64
At work	-22.31

- For a reduction of 1 min in
  - charging time, consumers are willing to pay 0.16 €/month.
  - waiting time, consumers are willing to pay 0.82 €/month.
- Difference in WTP between 0% and 100% renewables is 100*0.42 € = 42 €/month.
- For inductive charging compared to cable charging, the WTP is 8.38 €/month.
- Consumers are indifferent between tethered and inductive charging when tethered charging costs 50 €/month and inductive charging costs 58.38 €/month.
- Consumers are willing to pay 22.31 €/month more for charging at home, compared to charging at work.

3. Results
WTP for a reduction in charging duration (1/2)

For a reduction from 8 h to 10 min, consumers are willing to pay 8.09*4 h + 10.17*3,5 h + 7.64 = **75.58 €/month for all charging processes.**

Change in WTP for lower charging duration at specific time intervals (€/min per month)



For a reduction of 20 min in charging time (30 min →10 min), consumers are willing to pay 0.38 €/min per month, i.e. **7.64 €/month**.

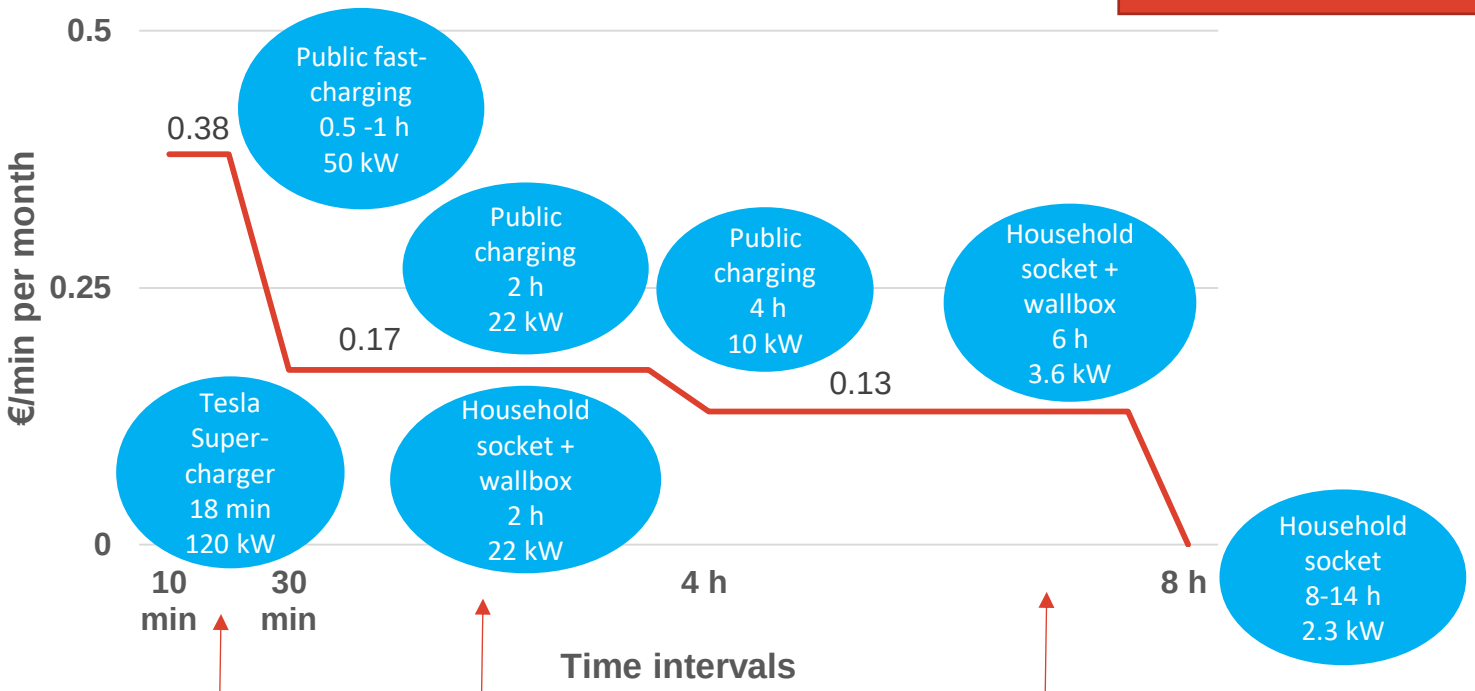
For a reduction of 1 h in charging time (e.g. 2 h→1 h), consumers are willing to pay 0.17 €/min per month, i.e. **10.17 €/month.**

For a reduction of 1 h in charging time (e.g. 8 h→7 h), consumers are willing to pay 0.13 €/min per month, i.e. **8.09 €/month.**

3. Results
WTP for a reduction in charging duration (2/2)

For a reduction from 8 h to 10 min, consumers are willing to pay 8.09*4 h + 10.17*3,5 h + 7.64 = **75.58 €/month for all charging processes.**

Change in WTP for lower charging duration at specific time intervals (€/min per month)



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5. Conclusions and Future Research

Respondents prefer charging (in order of importance)

- at the lowest costs;
- with shorter charging durations;
- at home to at work to roadside;
- with a higher share of renewable energies;
- with lower waiting times;
- inductively to cable-charging.

Over the whole range of time intervals, for a reduction of 1 min in

- charging time, consumers are willing to pay 0.15 €/month.
- waiting time, consumers are willing to pay 0.80 €/month.
- Significant preference heterogeneity between classes
- All attributes are significant for the whole sample, but not for all classes

Further analyze

- different segments (e.g. early adopters, (non-) experts, EV owners)
- regional & geographical differences of WTP
- policy implications

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