Driver Preferences for Flexible Electric Vehicle Charging Features

A discrete choice experiment

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CMK CENTRE FOR ENVIRONMENTAL SCIENCES 25 YEARS
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Contents

- Introduction and application of discrete choice experiments for flexibility provision
- Experimental setup and analysis
- Pilot results
- Next steps and further research

Discrete choice experiments (DCEs)

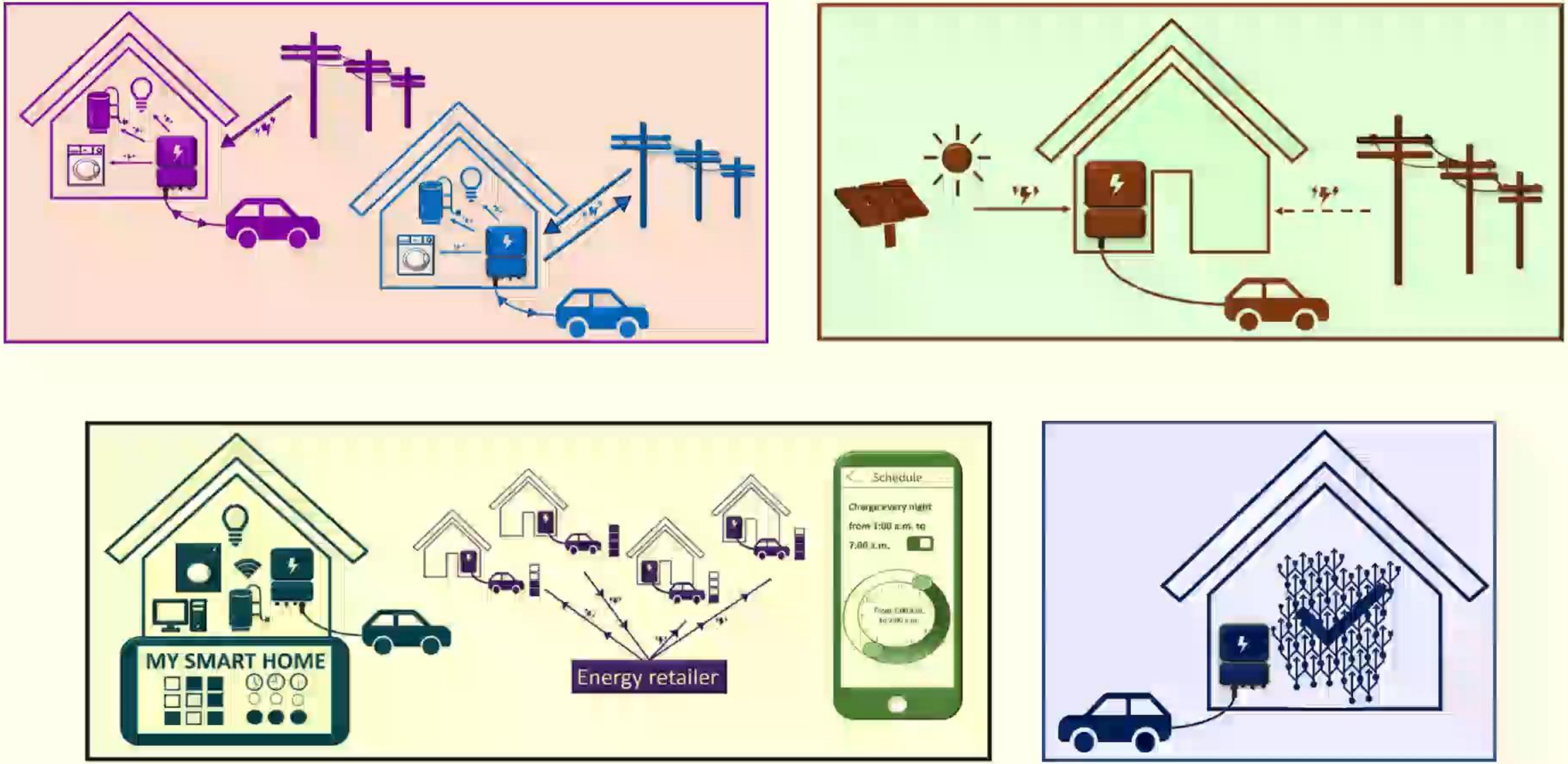
- Research technique used to measure consumer preferences.
- Data collected through surveys that present respondents with a set of hypothetical choices
- Advantage DCE – Measure preferences non-market goods/services
  - Valuation of non-market goods or services
- Results have demonstrated value!

Application of DCEs for flexibility

- **Pricing and remuneration**: Understanding the compensation drivers need for flexibility services to sustain their utility can guide us in formulating effective pricing strategies for advanced chargers.
- **Find barriers to adoption**: Find consumer characteristics that correlate with choices
    - Possibility for other interventions that could reduce these barriers
- **Modeling flexibility provision**: Using preferences for different charging features and their willingness to adopt and use these features under different price and reward (implicit interest rate) scenarios

EV charging choice context – given to survey-takers

- Assume that you drive an electric car, as will likely be the case in the next decades
- You have a simple charger that works like your phone or laptop charger – charging immediately at full speed once it is plugged in
- Upgrading to an advanced charger would offer electricity bill savings.
- Your new charger would last for ten years
- There are four advanced charging features to consider


MY SMART HOME
Energy retailer
Schedule
Charge every night
from 1:00 a.m. to
7:00 a.m.

Attribute table

Attributes	Level 1	Level 2	Level 3	Level 4
Price of charger and installation	€ 300	€ 1,600	€ 2,900	€ 4,200
Annual reward for using charging features	€ 30	€ 290	€ 550	€ 810
Solar-charging capability	Yes	No		
Two-way charging capability	Vehicle to home	Vehicle to home and grid	None	
Smart charging	By your smart home management system	By your energy retailer	By yourself using your smartphone	None. The vehicle will begin charging once plugged in until full capacity.
Peak electricity-use management	Yes	No		

Base attribute-level

(represents the reference point or default option for comparison)

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Sample choice card

If you drove an EV, would you buy a charger that has advanced charging features?

	Charger 1	**Charger 2**	**Use your current charger**
Smart charging ?	By your energy retailer	By your energy retailer	The current charger has no advanced features. It simply charges your car at the regular price until it is fully charged. You would not buy any new charger. You would not receive any reward for using the current charger.
Solar charging ? (would require existing or additional investment in household solar panels)	Yes	No	
Two-way charging ?	Vehicle to home and grid	Vehicle to home	
Peak electricity-use management ?	Yes	No	
Your reward for using the advanced charging features (reflected on your electric bill)	€ 810 annually (€ 8100 total over ten years)	€ 550 annually (€ 5500 total over ten years)	
Price of charger (including installation)	€ 4200	€ 2900	
	◯	◯	◯

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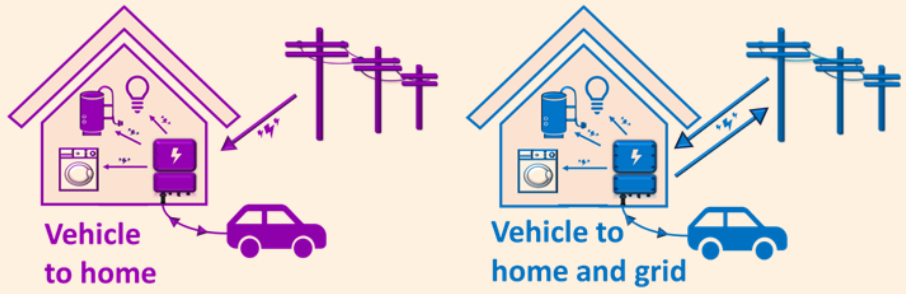
	○	○	○

Two-way charging

Use the car's battery to **power the appliances in your home**. Additionally, you can sell **electricity from your car back to the grid**.



Implicit discount rates (IDR)

	Charger 1
Smart charging ?	
Solar charging ? (would require existing or additional investment in household solar panels)	
Two-way charging ?	
Peak electricity-use management ?	
Your reward for using the advanced charging features (reflected on your electric bill)	€ 810 annually (€ 8100 total over ten years)
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	○

$$0 = \text{NPV} = \sum_{t=1}^{T} \frac{\text{Annual reward\_t}_j}{(1+\mathbf{IDR}_j)^t} - \text{Price}_j$$

Given a 10 lifetime of the charger (t=10), there is an IDR for each charger *j*.

Analysis: multinomial logistic regression

V_{ij} = ASC_{ij} + βSmart home management $system_{ij}$ + β Control by $retailer_{ij}$ + β Control by $user_{ij}$ + β Solar-exclusive $charging_{ij}$ + β Vehicle to $home_{ij}$ + β Vehicle to home and $grid_{ij}$ + β Peak-electricity use $management_{ij}$ + β IDR_{ij}

- V_{ij} = Observed utility of alternative *j* for individual *i*
  - Choices in the DCE used as a proxy for utility
  - Binary variable in the model - 1 if the alternative is chosen, and 0 if it is not chosen

- Coefficients (β) indicate how each attribute affects utility.

- ASC_{ij} indicates the baseline preference for a new charger.

Pilot results – advanced charger adoption (main effects)

	Attribute	Coefficient	MRS =[(b_attribute/b_IDR)]
	ASC A	1.70646***	-
	ASC B	1.321**	-
Smart charging	Control by a smart home management system (SHMS)	-0.61024	-37%
	Control by energy retailer	-0.68591	-42%
	Control by user (using a smartphone)	-0.02612	-2%
	Solar-exclusive charging (option)	0.48618**	30%
Two-way charging	Vehicle to home (V2H)	0.38294	24%
	Vehicle to home and grid (V2HG)	0.16947	10%
	Peak electricity use management (dynamic load balancing)	-0.11756	-7%
	IDR	0.01629**	-
	*** p<0.01, **p<0.05, *p<0.10		
	n=210 (30 survey-takers)		

- Solar charging increases utility
- Higher discount rate on the investment increases utility
- Smart charging options decrease utility (statistically insignificant)
- Varied discount rates required to offset the change in utility for each feature

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Choosing between a charger controlled by the retailer and a charger that operates simply by plugging, holding other variables constant, **the sample has a 34% probability of choosing the retailer-controlled charger.**

$$P = \frac{1}{1 + e^{-(\beta x)}}$$

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Next steps

- Sample of 900 survey-takers across Belgium – representative by gender, income, and age.
- Covariate analysis
  - Demographic information
  - Driving behavior
  - Risk preferences
  - Trust in energy provider
  - Experience with EVs
  - Early or late adaptor profile

Use these factors to find key drivers and barriers to technology adoption in Belgium. Also identify the likely adaptors of the technology.

Thank you!

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Charging feature interactions (example)

Logistic regression equation:

V_{ij} = ASC_{ij} + βSmart home management $system_{ij}$ + **β** Control by $retailer_{ij}$+ **β** Control by $user_{ij}$ + **β** Solar-exclusive charging $option_{ij}$ + **β** Vehicle to $home_{ij}$ + **β** Vehicle to home and $grid_{ij}$ + **β** Peak-electricity use $management_{ij}$ + **β** Control by $retailer_{ij}$ * Vehicle to home and $grid_{ij}$ + **β** IDR_{ij} + ε_{ij}

Where V_{ij} = the probability of individual i choosing alternative j

This term captures any synergies or differences in utility that arise when both features are considered together.

$V_{ij\ interaction}$ = β Control by $retailer_{ij}$ + β Vehicle to home and $grid_{ij}$ + β Control by $retailer_{ij}$ * Vehicle to home and $grid_{ij}$

Where $V_{ij\ interaction}$ = The utility of giving control to the retailer of a charger that has vehicle to home and grid capability

If you drove an EV and had a charger capable of V2H&G and smart charging, would you pay for extra provisions of a service agreement?

	Service agreement 1	Service agreement 2	No service agreement
Minimum battery level ?	30% (83 km range for a Nissan Leaf, for example)	10% (28 km range for a Nissan Leaf, for example)	Either schedule charging times yourself using your smartphone, connect the charger to a smart home management system, or skip smart charging by allowing the charger to begin charging when the car is plugged in. There is no fee for this option.
Portable power bank ?	No	Yes	
Emergency roadside charging assistance ?	Yes	No	
Charging data security ?	Yes	Yes	
Monthly smart charging service agreement fee (You would pay this fee out of the reward you earn by using the smart charging and two-way charging features)	€ 50 (€ 600 per year)	€ 10 (€ 120 per year)	
	○	○	○

Alexander

Attributes	Level 1	Level 2	Level 3	Level 4
Monthly smart charging service agreement fee (You would pay this fee out of the reward you earn by using the smart charging and two-way charging features)	€ 50	€ 30	€ 10	€ 0
Minimum battery level	50% (138 km range for a Nissan Leaf, for example)	30% charge (83 km range for a Nissan Leaf, for example)	10% charge (28 km range for a Nissan Leaf, for example)	0% (none)
Charging data security	Yes	No		
Emergency roadside charging assistance in Belgium	Yes	No		
Portable power bank	Yes	No		

Base attribute-level

(represents the reference point or default option for comparison.)

Alexander

Pilot results – service agreement adoption

Attribute	Coefficient	Willingness to Pay (b_attribute/b_fee)
ASC A	-2.3031***	-
ASC B	-3.0426***	-
Minimum battery level (coefficient corresponds to 1% increase)	0.0527***	€ 1.71
Portable power bank	0.3274	€ 10.63
Emergency roadside charging insurance	1.0776***	€ 35.02
Charging data security	1.1949***	€ 38.80
Monthly fee (in €)	-0.0308***	-
*** p<0.01, **p<0.05, *p<0.10		
n=210 (30 survey-takers)		

Large and significant alternative specific constants: suggests that the opt-out option was popular, indicating a preference among survey respondents to retain control of the charger rather than granting it to the retailer.

Significant coefficients for minimum battery level, emergency roadside charging insurance, charging data security: these service agreement provisions may incentivize users to transfer charger control. This could reduce needed compensation, lowering interest rates for smart and two-way charging purchases.