Deliverable 2.2

Analysis of the influence of individual consumers' characteristics on the engagement in energy system services

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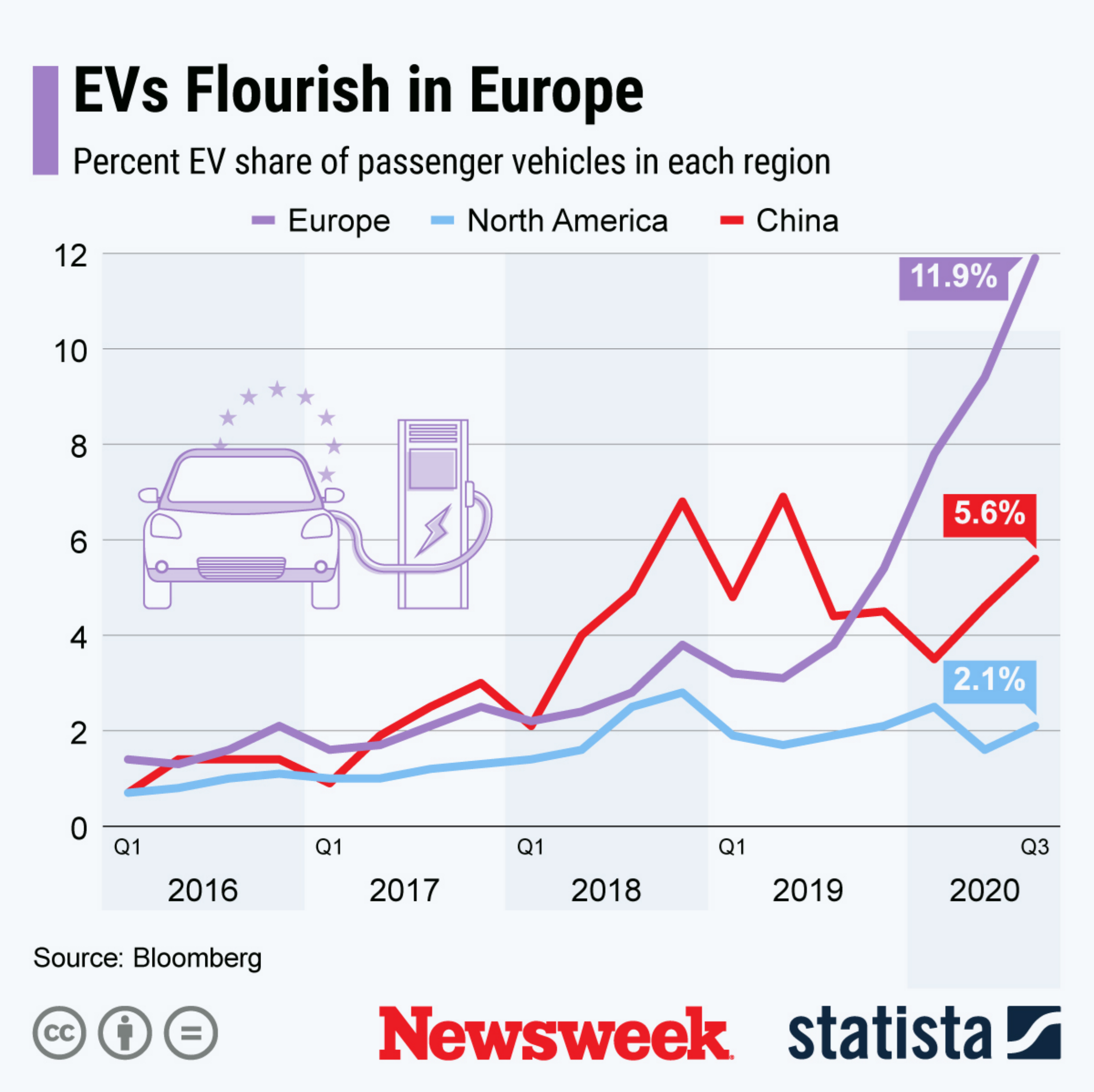
Driver Preferences for Flexible Electric Vehicle Charging Features

Upcoming demand for EVs

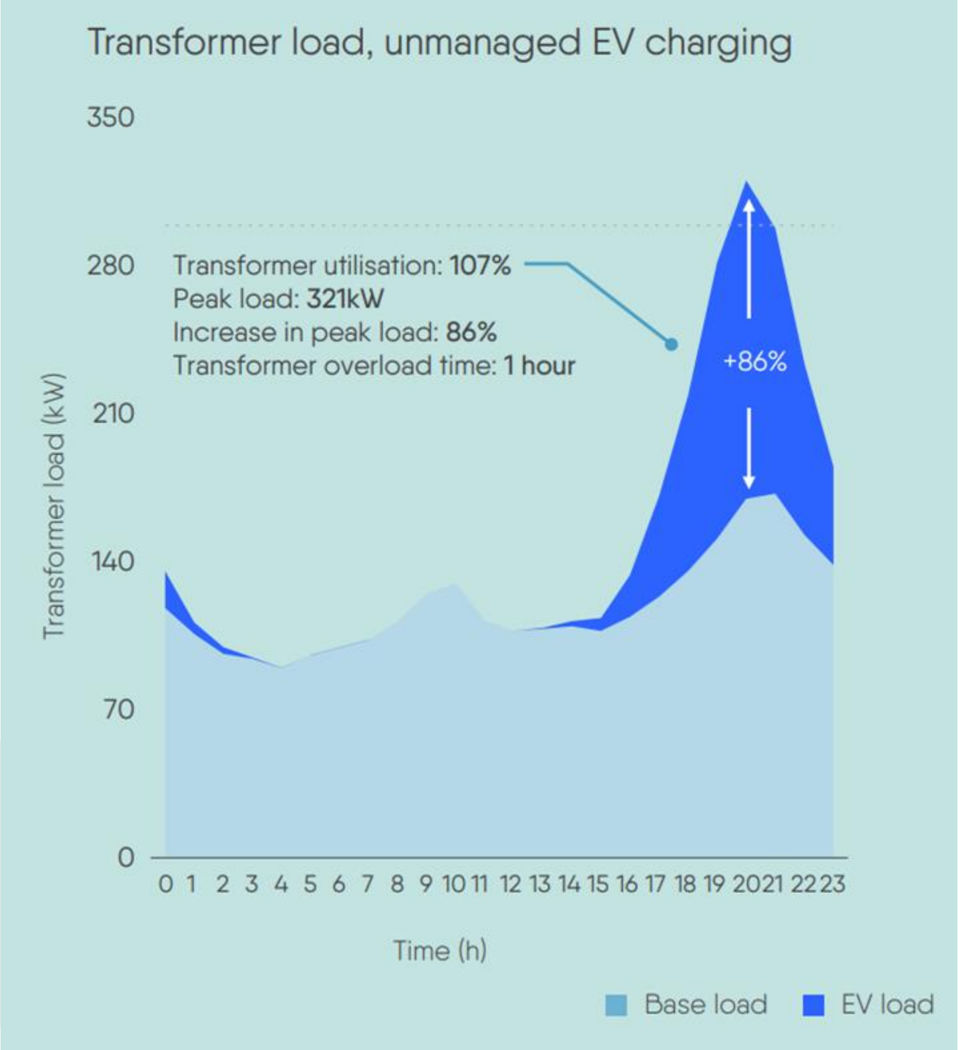
- EU proposal to phase out the sale of petrol-powered cars and vans by 2035 (Ramey 2021)
    - Aim to have at least 30 million EVs in operation by 2030 (European Commission)



Source: Bloomberg

Grid overload risk

- Eurelectric-EY model estimates that 85% of EV chargers will be residential (Colle et al., 2022)
- Left unmanaged, charging a Nissan Leaf would double typical household peak demand (Versi & Allington, 2016)



Research Questions

- How do individual electric vehicle (EV) charging features affect driver utility? (slide 15)
- How high is the flexibility discount rate gap for bidirectional charging? (slides 17-18)
- How do survey-taker characteristics affect preferences? (slide 19)

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		

Table shows the prices, rewards, and charging features that survey-takers see on choice cards (sample choice card in slide 12)

🟩 Base attribute-level

(represents the reference point or default option for comparison)

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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		

→ Prices cover the wide range of market prices for EV chargers listed by manufacturers and retailers

🟩 Base attribute-level

(represents the reference point or default option for comparison)

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		

→ Rewards calibrated to cover the wide range of discount rates needed for consumers to buy energy-efficient appliances per Stadelmann (2017)

🟩 Base attribute-level

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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		

Charging features suggested by consortium and supported in literature

🟩 Base attribute-level

(represents the reference point or default option for comparison)

Choice context

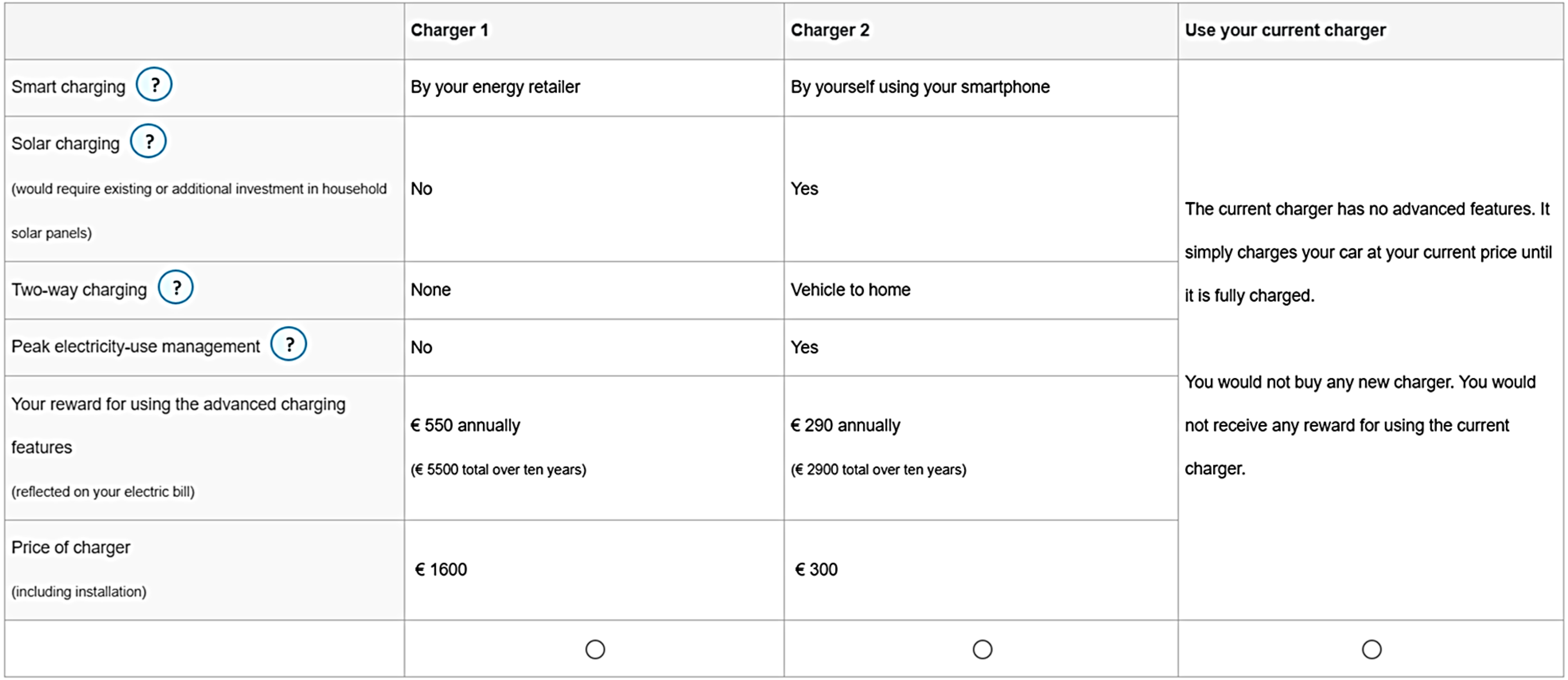
Video also given in Dutch or French in the survey

Electricity bill and pricing information – for choice context

- Algorithm (Qualtrics piped text) used in the survey to show approximately how much individual **survey-taker's electric bill would be if they had an EV** and continued their regular daily distance
- Information on current region-specific electric bill pricing structures (e.g. capacity tariff in Flanders) and upcoming changes (e.g. time of use pricing in Wallonia)
- Explicit statements of how each flexible charging feature could reduce the survey-taker's electric bill

Sample choice card

If you drove an EV, would you buy a charger 1, charger 2, or use a charger that does not have any of the features?

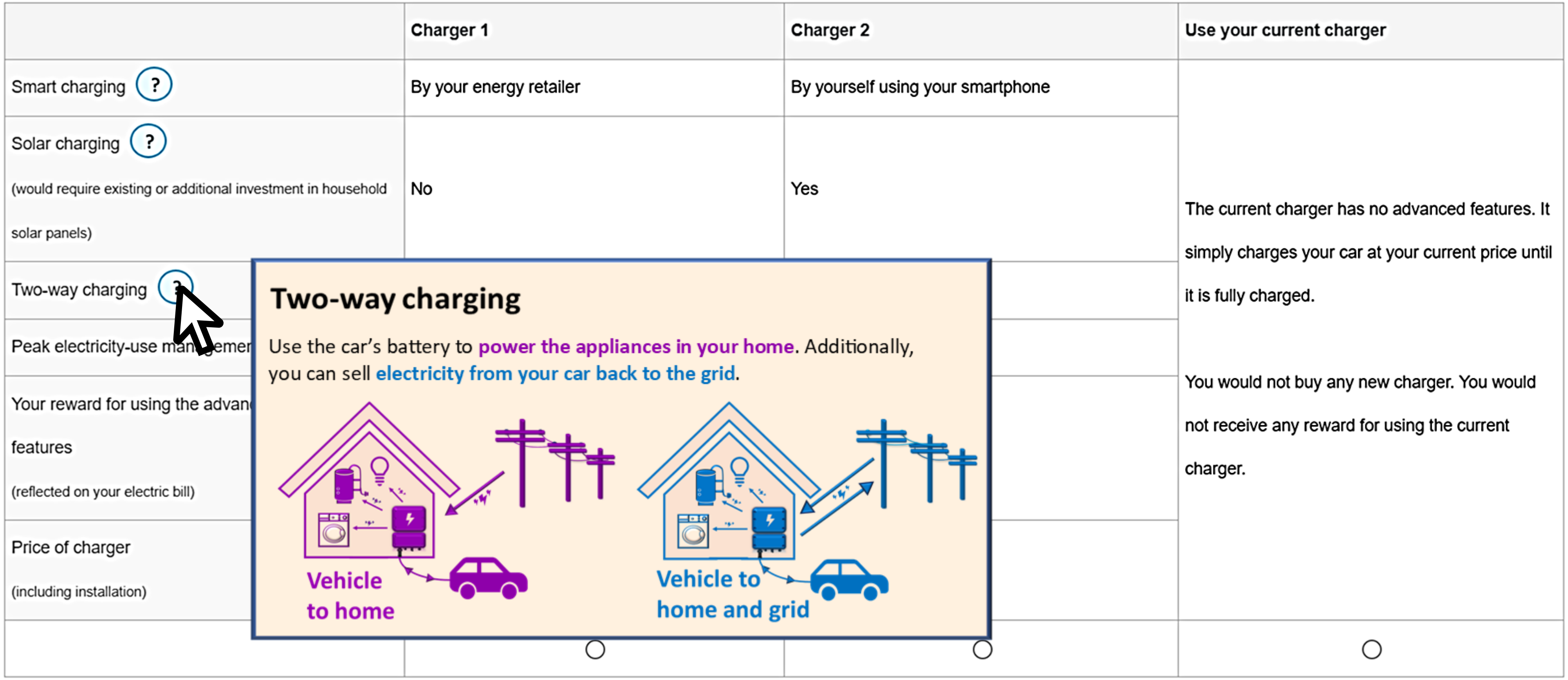


	Charger 1	**Charger 2**	**Use your current charger**
Smart charging ?	By your energy retailer	By yourself using your smartphone	The current charger has no advanced features. It simply charges your car at your current price until it is fully charged. You would not buy any new charger. You would not receive any reward for using the current charger.
Solar charging ? (would require existing or additional investment in household solar panels)	No	Yes	
Two-way charging ?	None	Vehicle to home	
Peak electricity-use management ?	No	Yes	
Your reward for using the advanced charging features (reflected on your electric bill)	€ 550 annually (€ 5500 total over ten years)	€ 290 annually (€ 2900 total over ten years)	
Price of charger (including installation)	€ 1600	€ 300	
	○	○	○

- Each survey taker answers eight choice cards where each hypothetical charger has unique combinations of prices, rewards, and charging features.
- Choice cards designed using JMP experimental software to efficiently isolate each of the main effects (slide 15) and relevant interaction effects (slide 16) – using prior data from a pilot survey of 30 responses

Sample choice card

If you drove an EV, would you buy a charger 1, charger 2, or use a charger that does not have any of the features?



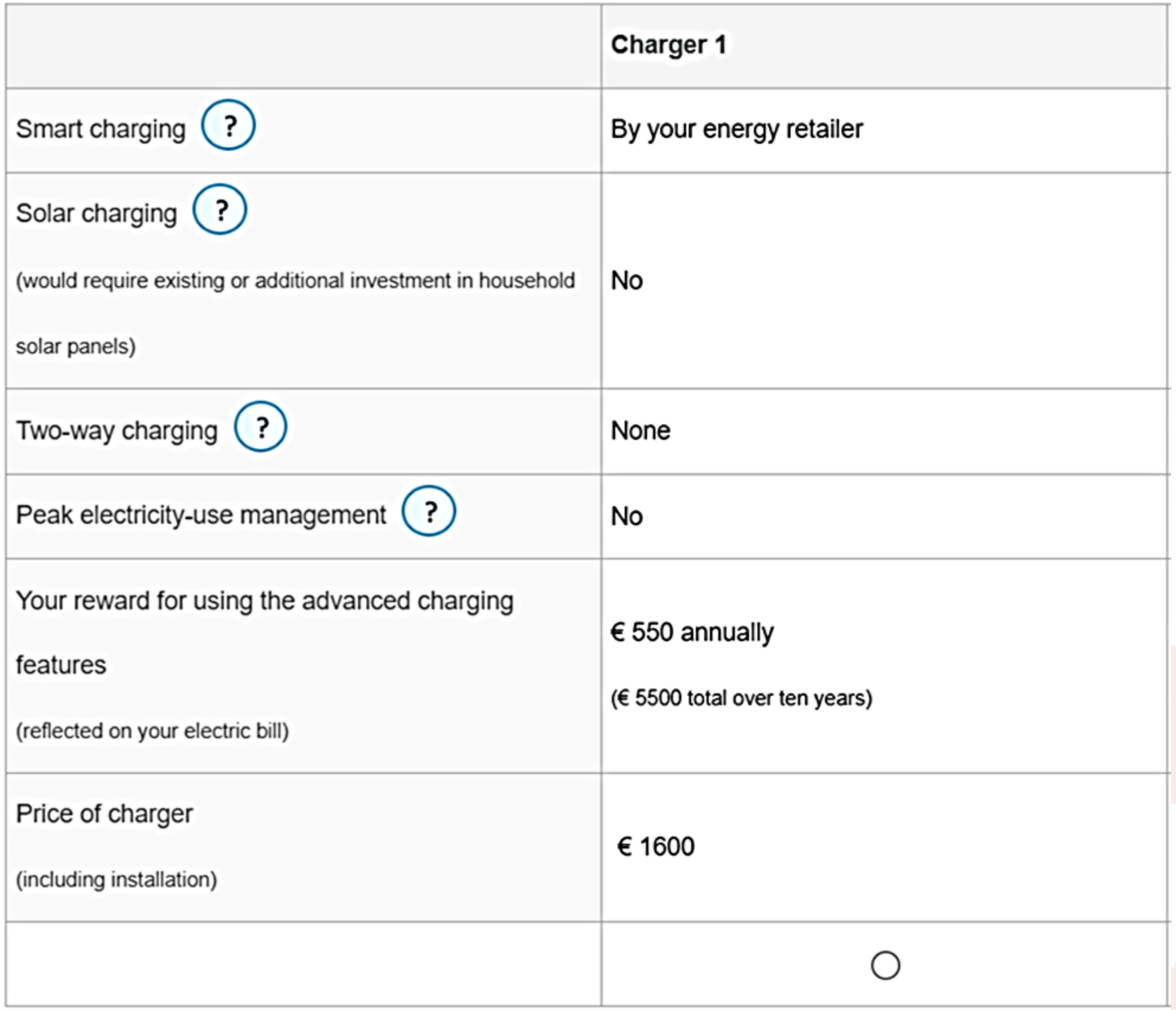
	Charger 1	Charger 2	Use your current charger
Smart charging ?	By your energy retailer	By yourself using your smartphone	The current charger has no advanced features. It simply charges your car at your current price until it is fully charged. You would not buy any new charger. You would not receive any reward for using the current charger.
Solar charging ? (would require existing or additional investment in household solar panels)	No	Yes	
Two-way charging ?			
Peak electricity-use managemen			
Your reward for using the advan features (reflected on your electric bill)			
Price of charger (including installation)			
	○	○	○

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**.

- Tooltips available for each of the features for an explanation and graphic of each feature's function for survey-taker understanding

Implicit discount rates (IDR)



	Charger 1
Smart charging ?	By your energy retailer
Solar charging ? (would require existing or additional investment in household solar panels)	No
Two-way charging ?	None
Peak electricity-use management ?	No
Your reward for using the advanced charging features (reflected on your electric bill)	€ 550 annually (€ 5500 total over ten years)
Price of charger (including installation)	€ 1600
	○

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

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

Analysis: main effects

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.
- $\boldsymbol{P} = \frac{1}{1+e^{-(\beta x)}}$ Coefficients can be converted into a probability – where P indicates the probability of individual *i* choose the alternative that includes that feature compared to not having that feature, holding all else constant
- Random coefficients method accounts for preference heterogeneity across individuals.

Analysis: main effects and interaction effects for smart and bidirectional charging

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$_{ij}$ +
βSmart home management system$_{ij}$ * Vehicle to home$_{ij}$ +
β Control by retailer$_{ij}$ * Vehicle to home$_{ij}$ +
β Control by user$_{ij}$ * Vehicle to home$_{ij}$ +
βSmart home management system$_{ij}$ * Vehicle to home and grid$_{ij}$ +
β Control by retailer$_{ij}$ * Vehicle to home and grid$_{ij}$ +
β Control by user$_{ij}$ * Vehicle to home and grid$_{ij}$

Analysis: marginal rates of substitution for feature-specific interest rates (main effects)

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}

MRS for each feature = β feature / β IDR

MRS = the amount of discount rate the average survey-taker will exchange for the feature

So, a positive MRS indicates that drivers are willing to lose money on investment in the feature and a negative MRS indicates that they need to earn money more than the initial price to be indifferent (even utility) about investing in the feature.

Analysis: marginal rates of substitution for feature combination-specific interest rates

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$_{ij}$ +

βSmart home management system$_{ij}$ * Vehicle to home$_{ij}$ + β Control by retailer$_{ij}$ * Vehicle to home$_{ij}$ +
β Control by user$_{ij}$ * Vehicle to home$_{ij}$ + βSmart home management system$_{ij}$ * Vehicle to home and grid$_{ij}$ +
β Control by retailer$_{ij}$ * Vehicle to home and grid$_{ij}$ + β Control by user$_{ij}$ * Vehicle to home and grid$_{ij}$

MRS for each feature = β Smart charging option/ β IDR + β Two-way charging option/ β IDR +

β Two-way charging option* Smart charging option / β IDR

For example

MRS for retailer and vehicle to home and grid = β Retailer/ β IDR + β vehicle to home and grid/ β IDR +

β Retailer* Vehicle to home ang grid/ β IDR

Latent class analysis and driver heterogeneity

Latent Class Analysis: identifies unobserved subgroups within a population based on responses from a discrete choice experiment. This analysis divides the sample into two classes, each representing distinct preferences for the attributes. We understand decision-making heterogeneity by regressing survey-taker characteristics on class membership.

V^Class 1$_{ij}$ = ASC$_{ij}$ + β^Class 1 Smart home management system$_{ij}$ + β ^Class 1 Control by retailer$_{ij}$ +
β ^Class 1 Control by user$_{ij}$ + β^Class 1 Solar-exclusive charging$_{ij}$ + β^Class 1 Vehicle to home$_{ij}$ +
β^Class 1 Vehicle to home and grid$_{ij}$ + β^Class 1 Peak-electricity use management$_{ij}$ + β^Class 1 IDR$_{ij}$

V^Class 2$_{ij}$ = ASC$_{ij}$ + β^Class 2 Smart home management system$_{ij}$ + β ^Class 2 Control by retailer$_{ij}$ +
β ^Class 2 Control by user$_{ij}$ + β^Class 2 Solar-exclusive charging$_{ij}$ + β^Class 2 Vehicle to home$_{ij}$ +
β^Class 2 Vehicle to home and grid$_{ij}$ + β^Class 2 Peak-electricity use management$_{ij}$ + β^Class 2 IDR$_{ij}$

Class 1 membership probability = β **Age**$_i$ + β **Gender**$_i$ + β **EV Experience**$_i$ + β **Price expectations**$_i$ +

β **Time of use pricing expections**$_i$ + β **Peak-use pricing expectations**$_i$ + β **Retailer trust**$_i$ + β **Daily driving distance**$_i$ +

β **Longest drive in last year**$_i$ + β **Annualized electric bill**$_i$ **+ β Education**$_i$ + β **Household income**$_i$

Incentivizing External Control of Electric Car Charging

Research Questions and method

- Can smart charging service agreement provisions nudge driver choices to allow the retailer to manage bidirectional charging? (slide 28)
- How much are drivers willing to pay for those provisions? (slide 29)

Attribute table

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		

Table shows the fees, and service agreement provisions that survey-takers see on choice cards (sample choice card in slide 26)

🟩 Base attribute-level

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

Attribute table

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		

→ Fees were taken by adding the market prices of a monthly lease of a portable power bank and emergency charging insurance combined. Other charging agreement provisions are software changes without added hardware to the smart charger.

🟩 Base attribute-level

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Attribute table

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		

Service agreement provisions found based on a literature review and interviews with regular drivers

🟩 Base attribute-level

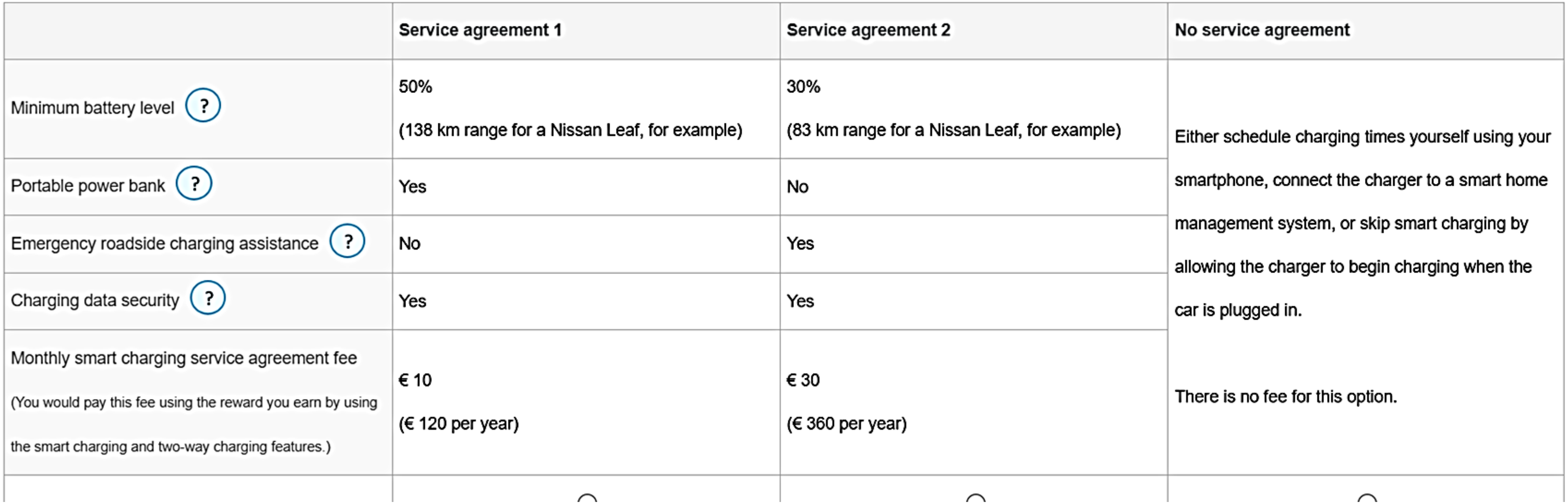
(represents the reference point or default option for comparison.)

Choice context

Video also given in Dutch or French in the survey

Sample choice card

Assume you have an EV and a charger that enables smart charging and vehicle to home and grid charging. Would you choose any of these service agreements to let the retailer control the charger?

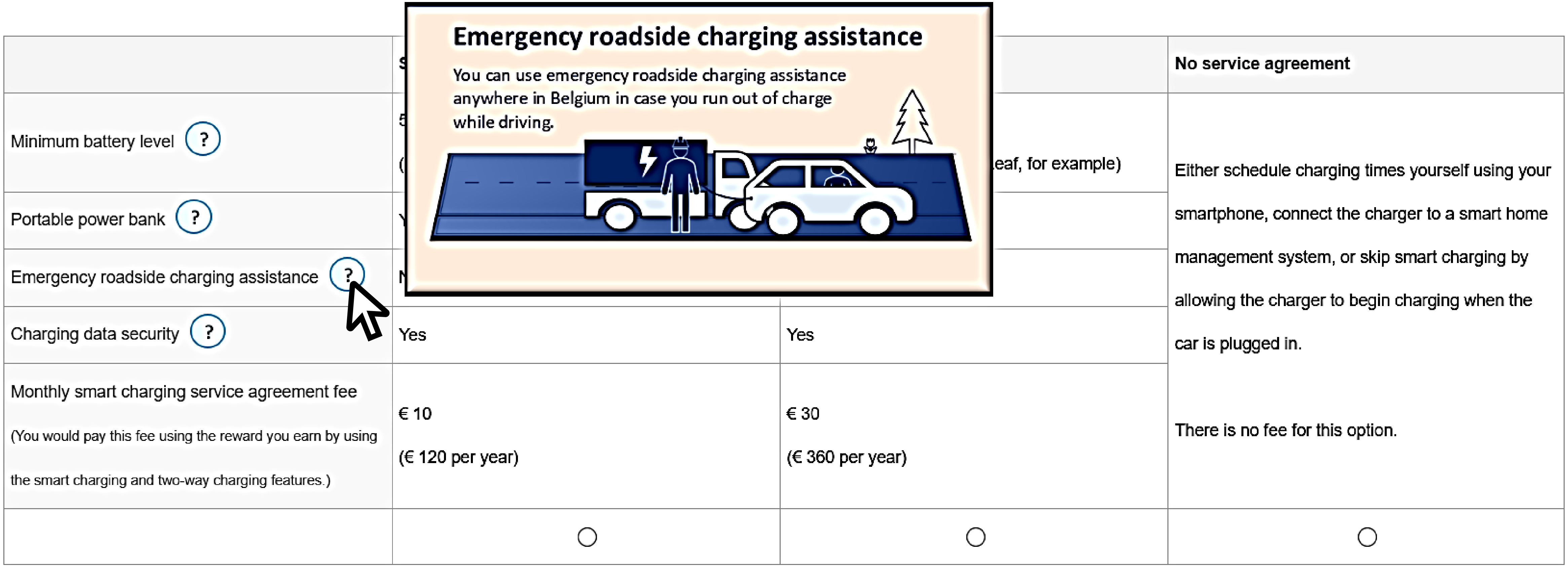


	Service agreement 1	Service agreement 2	No service agreement
Minimum battery level ?	50% (138 km range for a Nissan Leaf, for example)	30% (83 km range for a Nissan Leaf, for example)	Either schedule charging times yourself using your smartphone, connect the charger to a smart home management system, or skip smart charging by allowing the charger to begin charging when the car is plugged in.
Portable power bank ?	Yes	No	
Emergency roadside charging assistance ?	No	Yes	
Charging data security ?	Yes	Yes	
Monthly smart charging service agreement fee (You would pay this fee using the reward you earn by using the smart charging and two-way charging features.)	€ 10 (€ 120 per year)	€ 30 (€ 360 per year)	There is no fee for this option.
	○	○	○

- Each survey taker answers four choice cards where each hypothetical charger has unique combinations of prices, rewards, and charging features.
- Choice cards designed using JMP experimental software to efficiently isolate each of the main effects (slide 28) – using prior data from a pilot survey of 30 responses

Sample choice card

Assume you have an EV and a charger that enables smart charging and vehicle to home and grid charging. Would you choose any of these service agreements to let the retailer control the charger?



Emergency roadside charging assistance

You can use emergency roadside charging assistance anywhere in Belgium in case you run out of charge while driving.

	S		No service agreement
Minimum battery level ?	5 (	eaf, 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.
Portable power bank ?	Y		
Emergency roadside charging assistance ?	N		
Charging data security ?	Yes	Yes	
Monthly smart charging service agreement fee (You would pay this fee using the reward you earn by using the smart charging and two-way charging features.)	€ 10 (€ 120 per year)	€ 30 (€ 360 per year)	There is no fee for this option.
	○	○	○

- Tooltips available for each of the features for an explanation and graphic of each service provision for survey-taker understanding

Analysis: main effects

V_{ij} = ASC_{ij} + βMinimum battery level$_{ij}$ + β Portable power bank$_{ij}$ +

β Emergency roadside charging insurance + β Charging data security$_{ij}$ + 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**.
- $\boldsymbol{P} = \frac{1}{1+e^{-(\beta x)}}$ Coefficients can be converted into a probability – where P indicates the probability of individual *i* choose the alternative that includes that alternative compared to not having that alternative, holding all else constant
- ASC_{ij} indicates the baseline preference for a new charger.
- Random coefficients method accounts for preference heterogeneity across individuals.

Analysis: willingness to pay for (main effects)

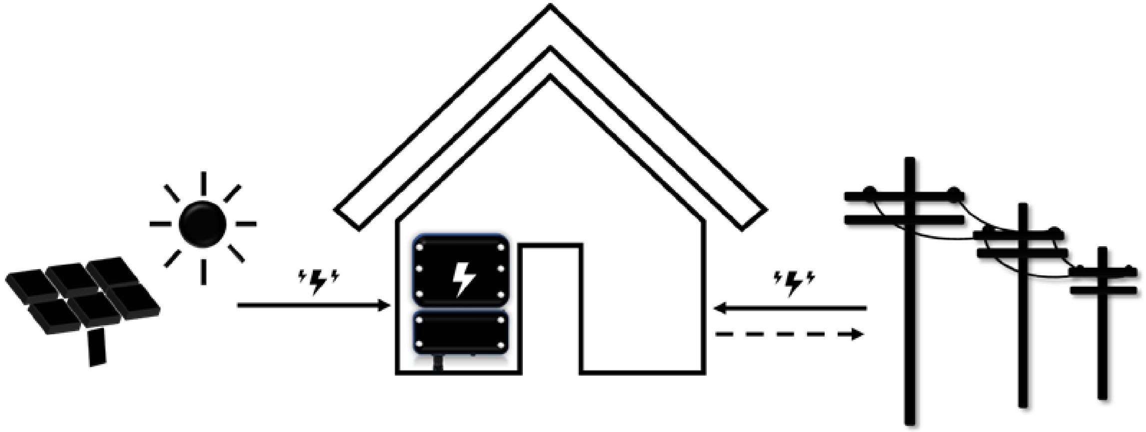
$V_{ij} = ASC_{ij} + \beta\text{Minimum battery level}_{ij} + \beta\text{ Portable power bank}_{ij} +$

$\beta\text{ Emergency roadside charging insurance} + \beta\text{ Charging data security}_{ij} + \beta\text{ IDR}_{ij}$

Willingness to pay (WTP) for each feature = β feature / β IDR

WTP = the amount of money the average survey-taker will exchange for the feature

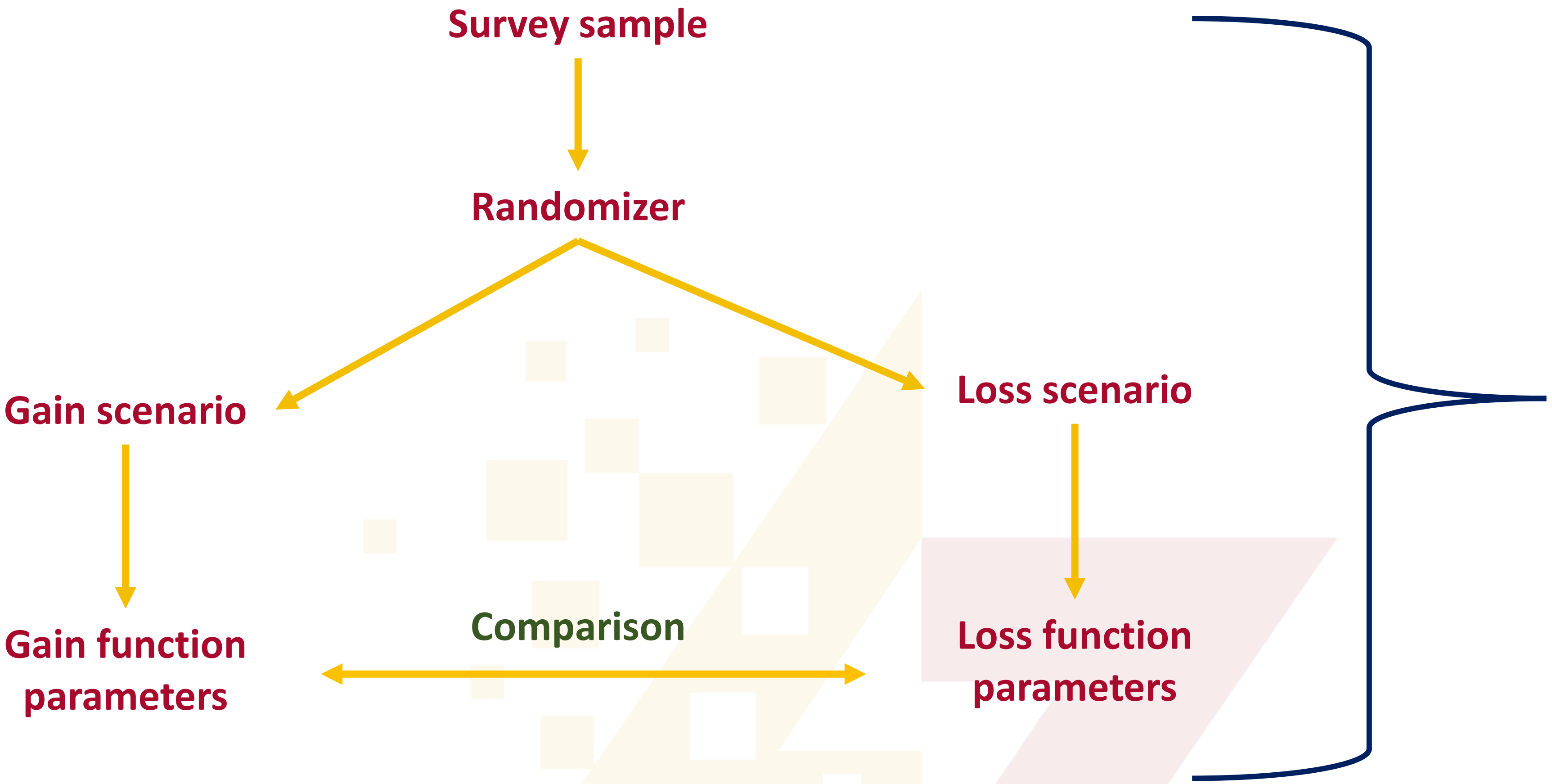
Prospect theoretical preferences for solar-battery system services



Research Questions

- Do LV users have a preference for who controls the battery in the context of system services using a solar battery system? (slide 36)
- How does gain and loss framing affect the choice to provide system services using solar-batteries? (slide 44)
- How do LV users weigh probability of gains and losses in the context of solar-battery system services? (slide 38)
    - Using cumulative prospect theory (CPT) as a framework

Dual DCEs to compare the power of gains to losses



Survey sample

Randomizer

Gain scenario

Loss scenario

Gain function parameters

Comparison

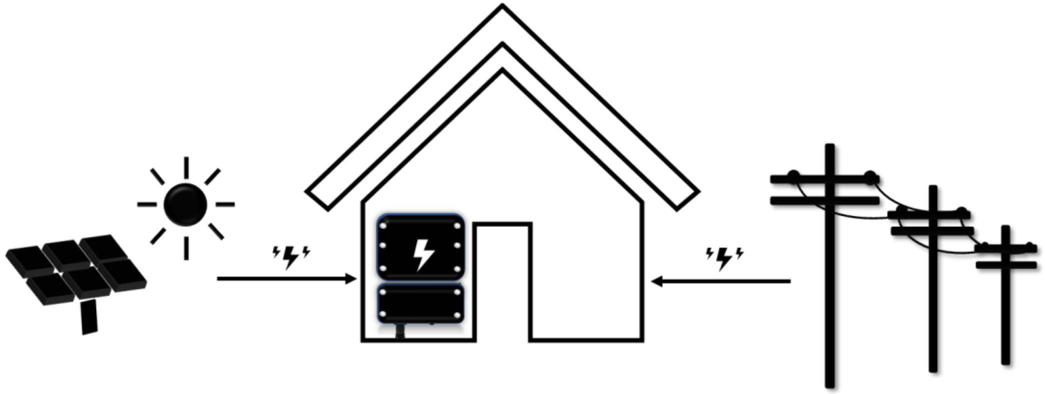
Loss function parameters

Like Park et al. (2023), but this time using CPT as the guiding framework

CPT in a discrete choice experiments – flexibility provision of solar batteries – gain scenario

Background: You own a home with solar panels and a battery system that stores solar energy during daylight hours. This system powers your home during peak demand hours, in the mornings and evenings.

Decision: Do you want to keep all your solar-produced energy for home use, or will you sell some to the grid?



Default Option: Personal Use
By using the stored energy for personal consumption during peak times, you are **guaranteed to save €100 on your electricity bill annually**.

Energy Selling Option: Grid Support Service
You have the option to sell some excess electricity from your battery back to the grid during peak usage hours, like the morning and evening.

Various energy-selling options are available, each involving some risk. Depending on local electricity market conditions (overall demand, renewable energy availability, and grid requirements), **your total annual reward can vary between €10 and €450**. Therefore, it is possible to earn more than the €100 in the default option, but it is also possible to earn less.

The range of probabilities associated with different earning levels ranges between 5% and 95%.

You will be able to make energy selling agreements with a public entity or a private entity.

CPT in a discrete choice experiments – sample choice card – gain scenario

Is you had a solar-battery system, would you sell some of your system’s excess energy to the grid when it is most needed?

	Energy selling agreement 1	Energy selling agreement 2	No selling agreement
Energy buyer (The entity that buys your solar-battery system's energy during peak-use hours)	Public DSO (Distribution System Operator) (Tooltip)	Private aggregator (Tooltip)	€ 100 annual reward (100% probability) (My household will use all my solar-battery's energy without selling any back to the grid)
Your annual reward (probability) (given as electric bill savings)	€300 (70% probability) €40 (30% probability)	€250 (80% probability) €50 (20% probability)	

- Each survey taker answers eight choice cards where each hypothetical charger has unique combinations of rewards, probabilities and energy buyers.

Gain utility function

$$V\_gain_{\{ij\}} = \alpha_{\{ij\}} + \theta\left[gain_{\{ij\}}^{high^{\lambda}} w\left(p_{\{ij\}}\right) + gain_{\{ij\}}^{low^{\lambda}}\left(1 - w\left(p_{\{ij\}}\right)\right)\right] + \beta X_{\{ij\}}$$

$$w\_gain(p) = \frac{\left\{{p_{\{ij\}}}^{\{\delta\}}\right\}}{\left\{\left({p_{\{ij\}}}^{\{\delta\}} + \left(1 - p_{\{ij\}}\right)^{\{\delta\}}\right)^{\left\{\frac{1}{\delta}\right\}}\right\}}$$

$$V\_gain_{\{ik\}} = \alpha_{\{ik\}} + \theta\left[gain_{\{ik\}} \quad \right]$$

Alternative j corresponds to energy selling options

Alternative k corresponds to opt-out (no selling agreement)

(Adapted utility functions from Wen et al. (2019))

CPT Utility Function

$$V\_gain_{\{ij\}} = \alpha_{\{ij\}} + \theta\left[{gain_{\{ij\}}^{high}}^{\lambda} w\left(p_{\{ij\}}\right) + {gain_{\{ij\}}^{low}}^{\lambda}\left(1 - w\left(p_{\{ij\}}\right)\right)\right] + \beta \mathbf{X}_{\{ij\}}$$

	Energy selling agreement 1	Energy selling agreement 2	No selling agreement
Energy buyer (The entity that buys your solar-battery system's energy during peak-use hours)	**Public DSO (Distribution System Operator) (Tooltip)**	**Private aggregator (Tooltip)**	€ 100 annual reward (100% probability) (My household will use all my solar-battery's energy without selling any back to the grid)
Your annual reward (probability) (given as electric bill savings)	€300 (70% probability) €40 (30% probability)	€250 (80% probability) €50 (20% probability)	

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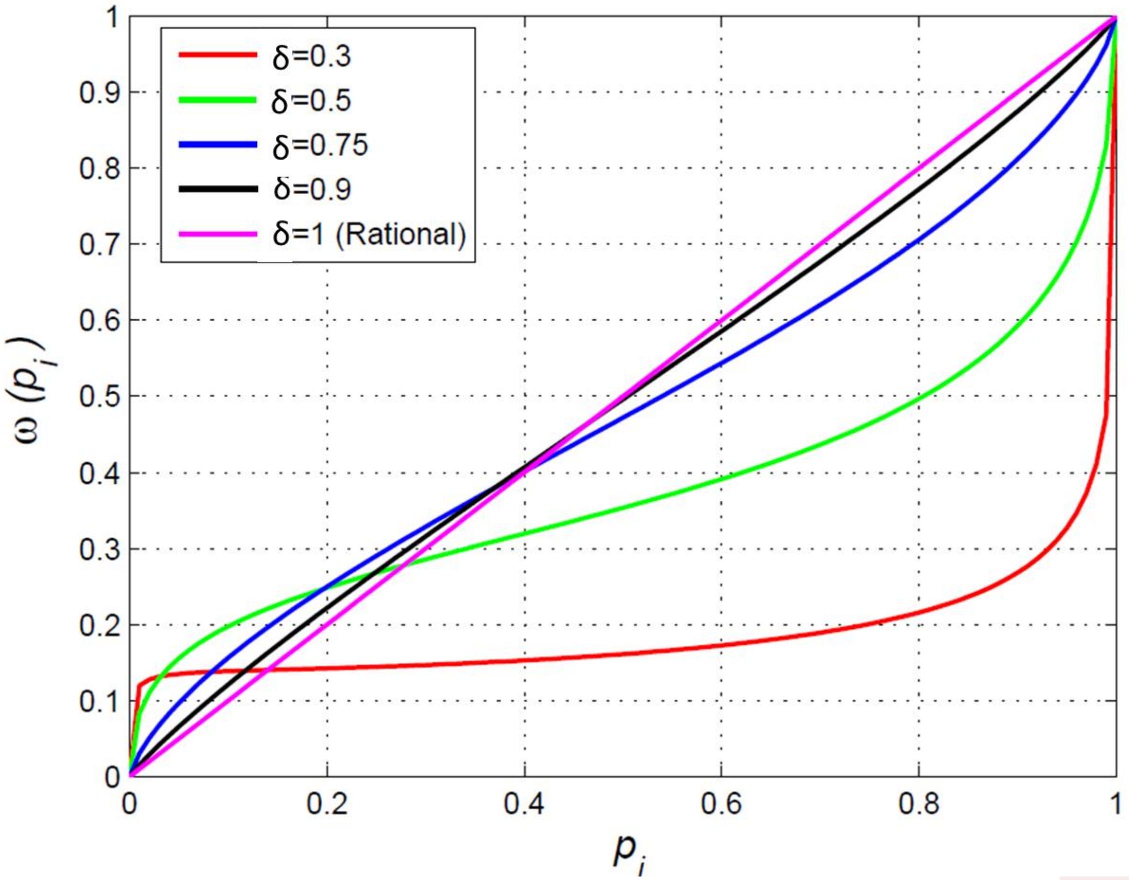
Weighting function

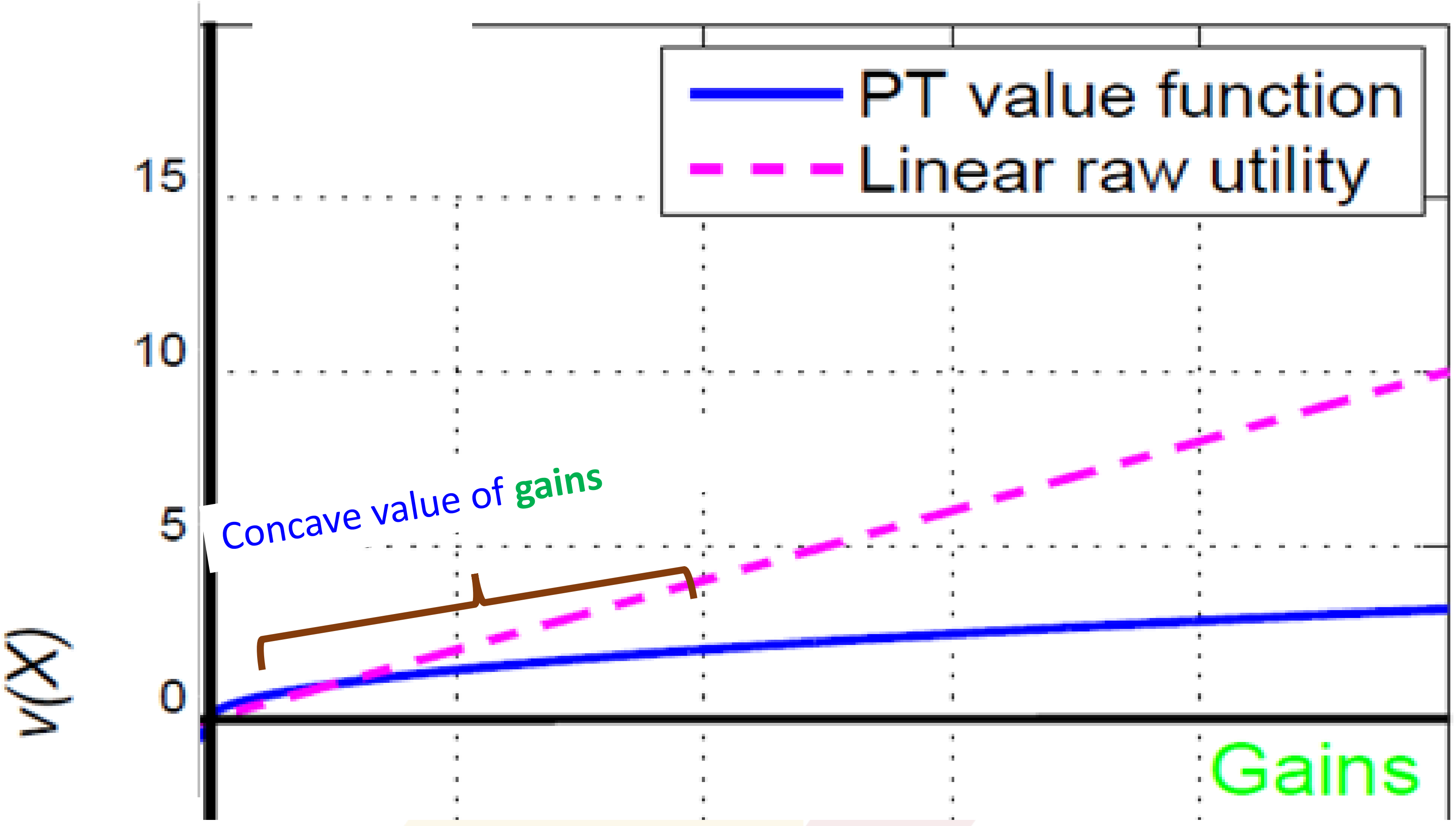
$$V\_gain_{\{ij\}} = \alpha_{\{ij\}} + \theta \left[gain_{\{ij\}}^{high^{\lambda}} \boldsymbol{w}(\boldsymbol{p}_{\{\boldsymbol{ij}\}}) + gain_{\{ij\}}^{low^{\lambda}} \left(1 - \boldsymbol{w}(\boldsymbol{p}_{\{\boldsymbol{ij}\}})\right)\right] + \beta X_{\{ij\}}$$



$$\boldsymbol{w}(\boldsymbol{p}) = \frac{\left\{\boldsymbol{p}_{\{\boldsymbol{ij}\}}{}^{\{\boldsymbol{\delta}\}}\right\}}{\left\{\left(\boldsymbol{p}_{\{\boldsymbol{ij}\}}{}^{\{\boldsymbol{\delta}\}} + \left(\boldsymbol{1} - \boldsymbol{p}_{\{\boldsymbol{ij}\}}\right)^{\{\boldsymbol{\delta}\}}\right)^{\left\{\frac{\boldsymbol{1}}{\boldsymbol{\delta}}\right\}}\right\}}$$

CPT Utility Function

$$V\_gain_{\{ij\}} = \alpha_{\{ij\}} + \theta \left[gain_{\{ij\}}^{high^{\lambda}} \boldsymbol{w}(\boldsymbol{p}_{\{ij\}}) + gain_{\{ij\}}^{low^{\lambda}} \left(1 - \boldsymbol{w}(\boldsymbol{p}_{\{ij\}})\right) \right] + \beta X_{\{ij\}}$$

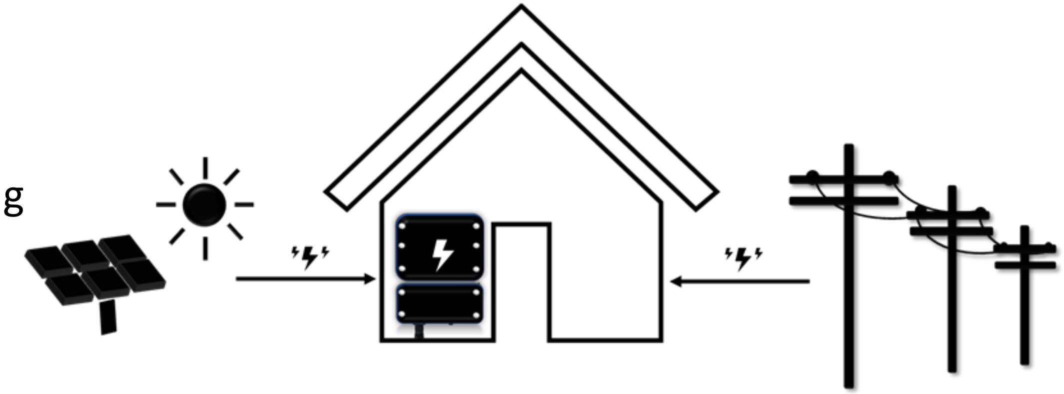


Concave value of **gains**

CPT in a discrete choice experiments – flexibility provision of solar batteries – loss scenario

Background: You have solar panels on your home and a home battery. This system stores solar energy during the day that you can use to power your home during peak demand hours, in the mornings and evenings. However, electricity prices are about to increase. So, while other household bills will increase by more, **your annualized electricity bill will still increase by €100**.

Decision: Do you want to keep all your solar-produced energy for home use, or will you sell some to the grid to potentially **mitigate your electric bill increase**?



Default Option: Personal Use
By utilizing your stored energy solely for personal consumption during peak times, your **electric bill will still increase by €100 per year.**

Energy Selling Option: Grid Support Service
You have the option to sell some excess electricity from your battery back to the grid during peak usage hours, like the morning and evening.

Various energy-selling options are available, each involving some risk. Depending on the local electricity market conditions (such as overall demand, renewable energy availability, and grid requirements), **the actual increase in your annual bill could vary between €5 and €600.** Thus, it is possible that an energy-selling option could result in a lesser increase than the €x seen with the default option, but there is also possible that your loss could be greater.

The range of probabilities associated with different losses ranges between 5% and 95%.

You will be able to make energy selling agreements with a public entity or a private entity.

CPT in a discrete choice experiments – sample choice card – loss scenario

Is you had a solar-battery system, would you sell some of your system’s excess energy to the grid when it is most needed?

	Energy selling agreement 1	Energy selling agreement 2	No selling agreement
Energy buyer (The entity that buys your solar-battery system's energy during peak-use hours)	Public DSO (Distribution System Operator) (Tooltip)	Private aggregator (Tooltip)	€ 100 annual loss (100% probability) (My household will use all my solar-battery's energy without selling any back to the grid)
Your annual loss (probability) (given as an electric bill increase)	€20 (70% probability) €160 (30% probability)	€30 (60% probability) €130 (40% probability)	

- Each survey taker answers eight choice cards where each hypothetical charger has unique combinations of losses, probabilities and energy buyers.

Loss utility functions

$$V\_loss_{\{ij\}} = \alpha_{\{ij\}} + \varphi\left[loss_{\{ij\}}^{Low^{\lambda}} w\left(p_{\{ij\}}\right) + loss_{\{ij\}}^{High^{\lambda}}\left(1 - w\left(p_{\{ij\}}\right)\right)\right] + \beta X_{\{ij\}}$$

$$w(p) = \frac{\left\{p_{\{ij\}}{}^{\{\gamma\}}\right\}}{\left\{\left(p_{\{ij\}}{}^{\{\gamma\}} + \left(1 - p_{\{ij\}}\right)^{\{\gamma\}}\right)^{\left\{\frac{1}{\gamma}\right\}}\right\}}$$

$$V\_loss_{\{ik\}} = \alpha_{\{ik\}} + \varphi\left[loss_{\{ik\}}\quad\right]$$

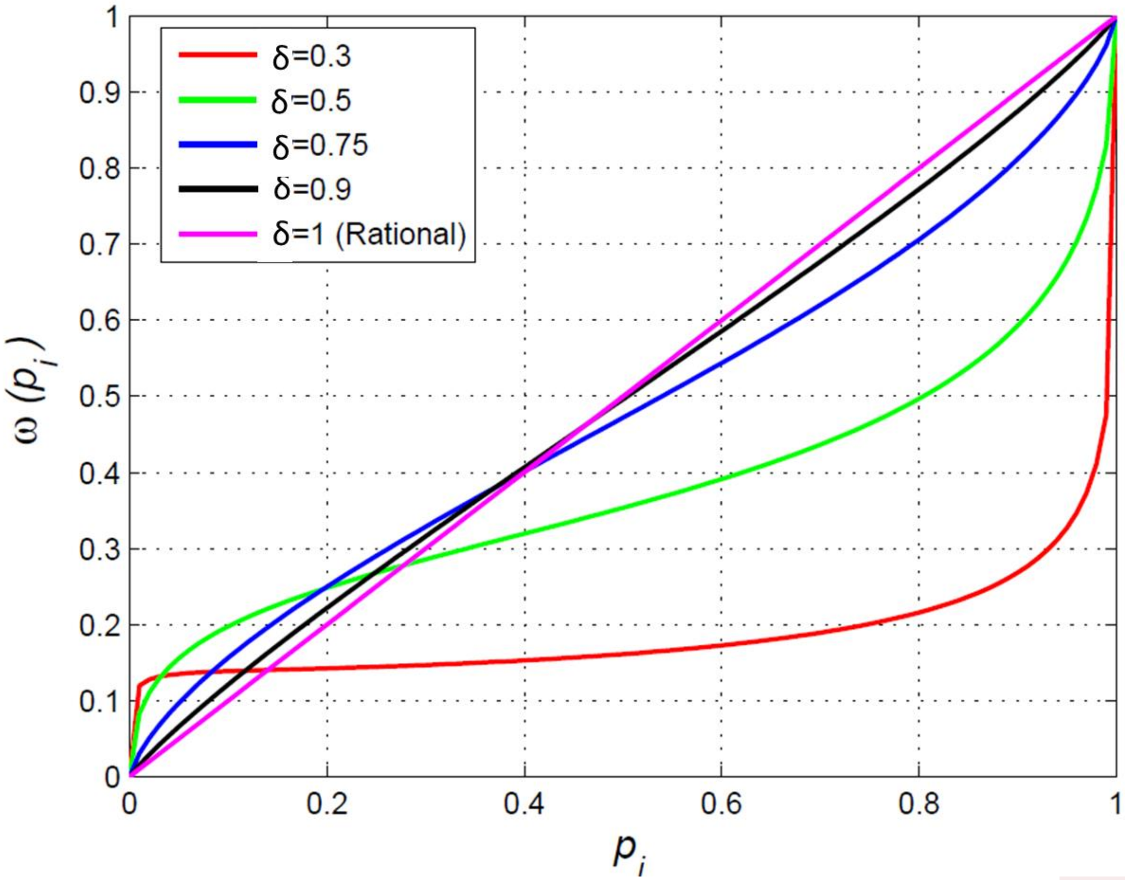
Alternative j corresponds to energy selling options

Alternative k corresponds to opt-out (no selling agreement)

(Adapted utility functions from Wen et al. (2019))

Weighting function

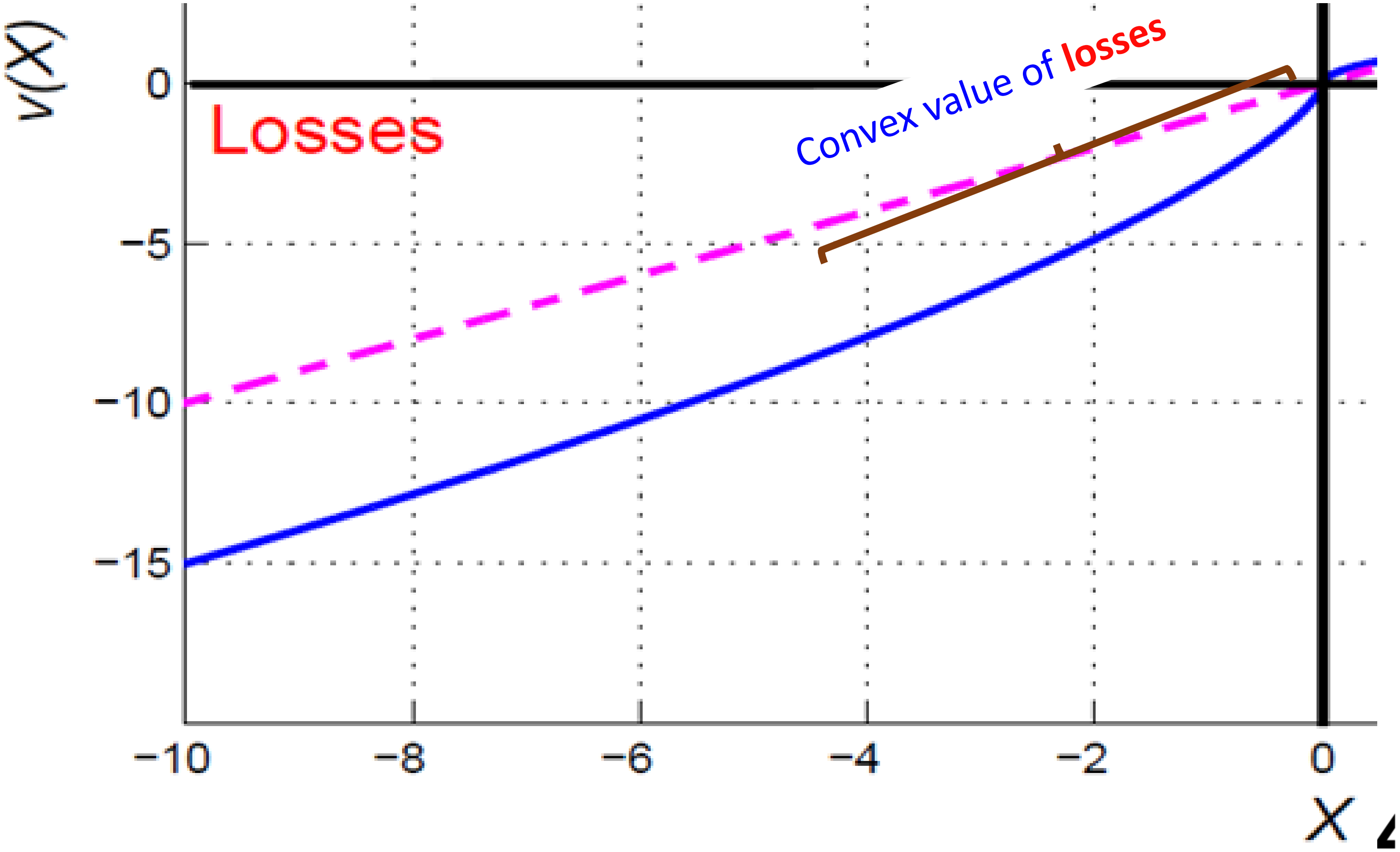
$$V\_loss_{\{ij\}} = \alpha_{\{ij\}} + \theta\left[loss_{\{ij\}}^{high^{\lambda}}\boldsymbol{w}(\boldsymbol{p}_{\{\boldsymbol{ij}\}}) + loss_{\{ij\}}^{low^{\lambda}}\left(1 - \boldsymbol{w}(\boldsymbol{p}_{\{\boldsymbol{ij}\}})\right)\right] + \beta X_{\{ij\}}$$



$$\boldsymbol{w}(\boldsymbol{p}) = \frac{\left\{\boldsymbol{p}_{\{\boldsymbol{ij}\}}{}^{\{\boldsymbol{\delta}\}}\right\}}{\left\{\left(\boldsymbol{p}_{\{\boldsymbol{ij}\}}{}^{\{\boldsymbol{\delta}\}} + \left(\boldsymbol{1} - \boldsymbol{p}_{\{\boldsymbol{ij}\}}\right)^{\{\boldsymbol{\delta}\}}\right)^{\left\{\frac{\boldsymbol{1}}{\boldsymbol{\delta}}\right\}}\right\}}$$

CPT Utility Function

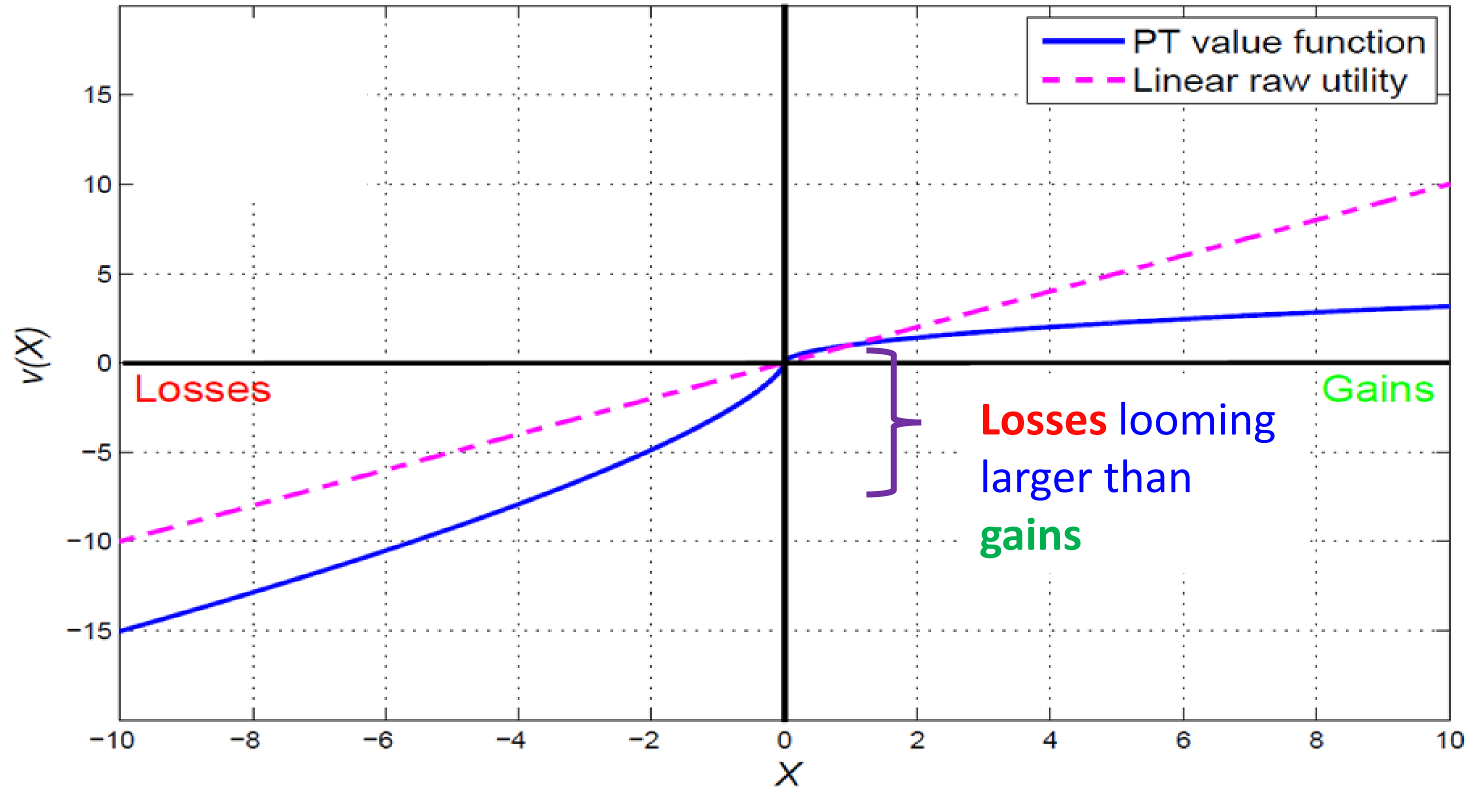
$$V\_loss_{\{ij\}} = \alpha_{\{ij\}} + \theta\left[loss_{\{ij\}}^{high^{\lambda}}\boldsymbol{w}\left(\boldsymbol{p}_{\{ij\}}\right) + loss_{\{ij\}}^{low^{\lambda}}\left(1 - \boldsymbol{w}\left(\boldsymbol{p}_{\{ij\}}\right)\right)\right] + \beta X_{\{ij\}}$$



Loss aversion

$$V\_loss_{\{ij\}} = \alpha_{\{ij\}} + \boldsymbol{\varphi} \left[loss_{\{ij\}}^{Low^{\lambda}} w\_loss(p_{\{ij\}}) + loss_{\{ij\}}^{High^{\lambda}} \left(1 - w\_loss(p_{\{ij\}})\right)\right] + \beta X_{\{ij\}}$$

$$V\_gain_{\{ij\}} = \alpha_{\{ij\}} + \boldsymbol{\theta} \left[gain_{\{ij\}}^{high^{\lambda}} w\_gain(p_{\{ij\}}) + gain_{\{ij\}}^{low^{\lambda}} \left(1 - w\_gain(p_{\{ij\}})\right)\right] + \beta X_{\{ij\}}$$



Hypothesis:
Abs(φ) > θ

Alexander

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