

Bridging Financing Gaps: Homeowners' Preferences for Residential PV Business Models

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Table of Contents

1. Background and Motivation
2. Data and Experiment
3. Results
4. Discussion
5. Appendix

Table of Contents

1. Background and Motivation

2. Data and Experiment

3. Results

4. Discussion

5. Appendix

Status quo of residential PV in Germany

Germany has a large amount of unused rooftop photovoltaic (PV) potential

- Existing literature suggests that the main barriers to solar PV adoption are...
 - the high upfront investment cost (e.g., Jager, 2006; Petrovich et al., 2019, 2021; Uz and Mamkhezri, 2024) and
 - a long amortization time (e.g., Priessner and Hampl, 2020).
- Can emerging business models tackle these barriers?

Emerging business models in the residential PV space

Renting could address the upfront investment cost

- Rental models can potentially enable homeowners without sufficient funds to benefit from solar PV.
- People prefer to buy rather than rent electric vehicles (e.g., Huang et al., 2021; Liao et al., 2019), and heating systems (e.g., Schleich et al., 2021).

Energy Clouds/Communities could further incentivize PV investments

- Solar PV systems often generate surplus electricity.
- Energy cloud: Members get a remuneration for surplus electricity which other members can use. In turn, they can use the other members' surplus energy when needed.

Table of Contents

1. Background and Motivation

2. Data and Experiment

3. Results

4. Discussion

5. Appendix

This paper

Explore homeowners' preferences regarding solar PV attributes and emerging business models

- We employ a discrete choice experiment (DCE).
- With the results we can analyze preferences and quantify them in terms of willingness-to-pay (WTP).

Online survey

- Conducted in the summer of 2023 in partnership with a regional utility
- 842 Single-family home owners

Attributes and attribute levels

Table 1: Attributes and attribute levels in the stated choice experiment

Attribute	Level
Total costs purchase (in €)	5,000*; 10,000*; 15,000; 20,000; 25,000**; 30,000**
Total costs rent-to-own (in €)	6,000*; 12,000*; 18,000; 24,000; 30,000**; 36,000**
Amortization time (in years)	10*; 13*; 16; 19; 22**; 25**
Self-consumption (in %)	20*; 30*; 40*; 50*; 60**; 70**; 80**; 90**
Energy sharing (Strom-Cloud)	None; Regional; Family & Friends

* = No battery; ** = Battery

The stated choice experiment

Table 2: Sample choice task (translated)

	Purchase	Purchase incl. Battery	Rent-to-own	Rent-to-own incl. Battery	No choice
Costs	€ 10,000	€ 25,000	€ 50 monthly (€ 12,000)	€ 125 monthly (€ 30,000)	
Amortization time	10 years	16 years	10 years	22 years	
Self-sufficiency	20%	60%	50%	60%	
Energy Cloud	Family & Friends	Regional	None	Regional	
I choose	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Table of Contents

1. Background and Motivation

2. Data and Experiment

3. Results

4. Discussion

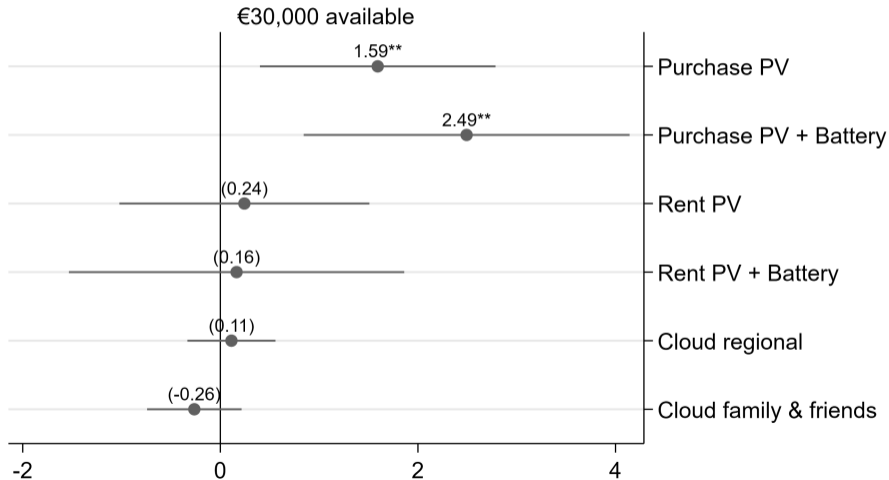
5. Appendix

Main effects

Table 3: Results from mixed logit models in preference space (robust z-statistics)

	Mean	Standard deviation	WTP [95 % CI]
Purchase PV	0.527 (1.596)	2.582*** (11.505)	
Purchase PV + battery	3.427*** (7.960)	2.914*** (11.871)	28.782 [22.010, 35.463]
Rent-to-own PV	-0.608 (-1.433)	3.092*** (9.950)	
Rent-to-own PV + battery	1.659*** (3.343)	3.715*** (12.884)	13.928 [6.404, 21.451]
Amortization time (in years)	-0.096*** (-8.536)	0.065*** (3.736)	-0.808 [-1.015, -0.602]
Self-sufficiency (in %)	0.042*** (10.885)	0.036*** (12.534)	0.350 [0.277, 0.423]
Energy cloud: Regional	0.272*** (2.579)	1.284*** (8.689)	2.284 [0.519, 4.050]
Energy cloud: Family & Friends	-0.044 (-0.378)	1.532*** (10.544)	
Costs (in 1,000 Euro)	-0.119*** (-15.299)		

Preference heterogeneity



Preference heterogeneity

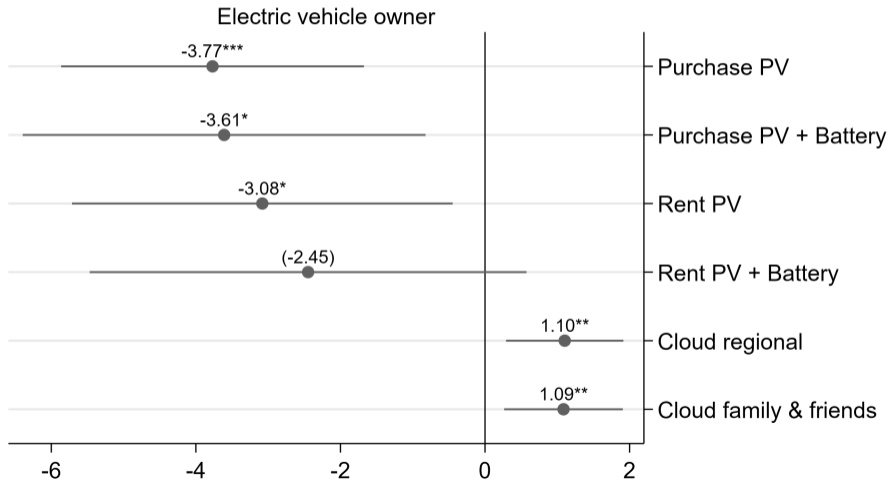


Table of Contents

1. Background and Motivation
2. Data and Experiment
3. Results
4. Discussion
5. Appendix

Discussion

Findings regarding solar PV system attributes

We find that homeowners show preferences for...

- Higher self-sufficiency
- Shorter amortization time
- Battery systems

⇒ These results confirm findings from previous literature (e.g., Jacksohn et al., 2019; Uz and Mamkhezri, 2024; Klein and Deissenroth, 2017; Petrovich et al., 2021, 2019)...

⇒ and the real world (Bundesverband Solarwirtschaft e.V., 2024).

Discussion

Findings regarding business models

Rental option

- Similar to findings from related literature (e.g., Huang et al., 2021; Schleich et al., 2021; Liao et al., 2019), people seem to prefer to purchase outright...
- ... especially those who have sufficient funds.

Energy cloud/Communities

- We find a general preference for regional energy sharing but not for a personalized option.
- EV owners have stronger preferences for energy sharing models compared to non-EV owners.

Thank you!

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Table of Contents

1. Background and Motivation
2. Data and Experiment
3. Results
4. Discussion
5. Appendix

Additional information

Variable	Observations	Mean
Ability to invest 30,000 Euro	842	.53
Eq. household income (in 1,000 €)	842	3.12
Above-average electricity consumption	842	.47
EV ownership	842	.08
Heat pump ownership	842	.07
Age	842	61.43
Female	842	.30
University degree	842	.56

Figure 1: Sample characteristics

Main effects

Table 4: Results from mixed logit models in preference and WTP space (robust z-statistics)

	Preference Space		WTP	WTP Space	
	Mean	Standard deviation	[95 % CI]	Mean	Standard deviation
Purchase PV	0.527 (1.596)	2.582*** (11.505)		3.535 (1.166)	-23.214*** (-8.903)
Purchase PV + battery	3.427*** (7.960)	2.914*** (11.871)	28.782 [22.010, 35.463]	28.157*** (7.326)	-26.470*** (-9.316)
Rent-to-own PV	-0.608 (-1.433)	3.092*** (9.950)		-4.564 (-1.257)	24.797*** (9.502)
Rent-to-own PV + battery	1.659*** (3.343)	3.715*** (12.884)	13.928 [6.404, 21.451]	16.464*** (4.549)	28.761*** (8.749)
Amortization time (in years)	-0.096*** (-8.536)	0.065*** (3.736)	-0.808 [-1.015, -0.602]	-0.798*** (-7.407)	-0.519*** (-3.808)
Self-sufficiency (in %)	0.042*** (10.885)	0.036*** (12.534)	0.350 [0.277, 0.423]	0.342*** (9.359)	0.283*** (5.552)
Energy sharing: Regional	0.272*** (2.579)	1.284*** (8.689)	2.284 [0.519, 4.050]	2.050** (2.249)	-10.744*** (-7.737)
Energy sharing: Family & Friends	-0.044 (-0.378)	1.532*** (10.544)		-0.277 (-0.277)	-12.470*** (-8.277)
Costs (in 1,000 Euro)	-0.119*** (-15.299)			-2.086*** (-19.760)	0.197 (0.875)

References I

- Youlin Huang, Lixian Qian, Didier Soopramanien, and David Tyfield. Buy, lease, or share? consumer preferences for innovative business models in the market for electric vehicles. 166:120639, 2021. ISSN 00401625. doi: 10.1016/j.techfore.2021.120639. URL <https://www.sciencedirect.com/science/article/pii/S0040162521000718>. PII: S0040162521000718.
- Anke Jacksohn, Peter Grösche, Katrin Rehdanz, and Carsten Schröder. Drivers of renewable technology adoption in the household sector. 81:216–226, 2019. ISSN 01409883. doi: 10.1016/j.eneco.2019.04.001. PII: S0140988319301070.
- Wander Jager. Stimulating the diffusion of photovoltaic systems: A behavioural perspective. *Energy Policy*, 34(14):1935–1943, 2006. ISSN 03014215. doi: 10.1016/j.enpol.2004.12.022. URL <https://www.sciencedirect.com/science/article/pii/S0301421505000248>.
- Martin Klein and Marc Deissenroth. When do households invest in solar photovoltaics? an application of prospect theory. 109:270–278, 2017. ISSN 03014215. doi: 10.1016/j.enpol.2017.06.067. PII: S0301421517304317.
- Fanchao Liao, Eric Molin, Harry Timmermans, and Bert van Wee. Consumer preferences for business models in electric vehicle adoption. 73:12–24, 2019. ISSN 0967070X. doi: 10.1016/j.tranpol.2018.10.006. URL <https://www.sciencedirect.com/science/article/pii/S0967070X17307862>. PII: S0967070X17307862.
- Beatrice Petrovich, Stefanie Lena Hille, and Rolf Wüstenhagen. Beauty and the budget: A segmentation of residential solar adopters. 164: 106353, 2019. ISSN 09218009. doi: 10.1016/j.ecolecon.2019.106353. PII: S0921800918312333.
- Beatrice Petrovich, Stefano Carattini, and Rolf Wüstenhagen. The price of risk in residential solar investments. 180:106856, 2021. ISSN 09218009. doi: 10.1016/j.ecolecon.2020.106856. PII: S0921800919321780.
- Alfons Priessner and Nina Hampl. Can product bundling increase the joint adoption of electric vehicles, solar panels and battery storage? explorative evidence from a choice-based conjoint study in austria. 167:106381, 2020. ISSN 09218009. doi: 10.1016/j.ecolecon.2019.106381. PII: S0921800918311480.

References II

- Joachim Schleich, Gengyang Tu, Corinne Faure, and Marie-Charlotte Guetlein. Would you prefer to rent rather than own your new heating system? insights from a discrete choice experiment among owner-occupiers in the uk. 158:112523, 2021. ISSN 03014215. doi: 10.1016/j.enpol.2021.112523. URL <https://www.sciencedirect.com/science/article/pii/S0301421521003931>.
- Dilek Uz and Jamal Mamkhezri. Household willingness to pay for various attributes of residential solar panels: Evidence from a discrete choice experiment. page 107277, 2024. ISSN 01409883. doi: 10.1016/j.eneco.2023.107277. URL <https://www.sciencedirect.com/science/article/pii/S0140988323007752>. PII: S0140988323007752.

Heterogeneity analysis

Table 5: Results from mixed logit models with interactions in preference space (robust z-statistics)

	Sufficient funds (dum)	Eq. hh income	Age (cont.)	Above-average electricity consumption p.c.	EV ownership	Heat pump	Undecided
Purchase PV	1.035*** (2.617)	0.109 (0.855)					
Purchase PV + battery	1.719*** (4.353)	0.226** (1.971)					
Rent-to-own PV	-0.241 (-0.536)	-0.057 (-0.362)					
Rent-to-own PV + battery	-0.507 (-0.975)	0.041 (0.256)					
Energy sharing: Regional	0.101 (0.446)	0.009 (0.122)					
Energy sharing: Family & Friends	-0.176 (-0.708)	-0.000 (-0.002)					

Heterogeneity analysis

Table 6: Results from mixed logit models with interactions in preference space (robust z-statistics)

	Sufficient funds (dum)	Eq. hh income	Age (cont.)	Above-average electricity consumption p.c.	EV ownership	Heat pump	Undecided
Purchase PV	1.035*** (2.617)	0.109 (0.855)	-0.044*** (-2.754)				
Purchase PV + battery	1.719*** (4.353)	0.226** (1.971)	-0.042** (-2.464)				
Rent-to-own PV	-0.241 (-0.536)	-0.057 (-0.362)	-0.046** (-2.233)				
Rent-to-own PV + battery	-0.507 (-0.975)	0.041 (0.256)	-0.050** (-2.258)				
Energy sharing: Regional	0.101 (0.446)	0.009 (0.122)	-0.000 (-0.051)				
Energy sharing: Family & Friends	-0.176 (-0.708)	-0.000 (-0.002)	-0.006 (-0.577)				

Heterogeneity analysis

Table 7: Results from mixed logit models with interactions in preference space (robust z-statistics)

	Sufficient funds (dum)	Eq. hh income	Age (cont.)	Above-average electricity consumption p.c.	EV ownership	Heat pump	Undecided
Purchase PV	1.035*** (2.617)	0.109 (0.855)	-0.044*** (-2.754)	-0.635* (-1.711)			
Purchase PV + battery	1.719*** (4.353)	0.226** (1.971)	-0.042** (-2.464)	-0.496 (-1.357)			
Rent-to-own PV	-0.241 (-0.536)	-0.057 (-0.362)	-0.046** (-2.233)	-0.277 (-0.627)			
Rent-to-own PV + battery	-0.507 (-0.975)	0.041 (0.256)	-0.050** (-2.258)	0.381 (0.821)			
Energy sharing: Regional	0.101 (0.446)	0.009 (0.122)	-0.000 (-0.051)	0.306 (1.418)			
Energy sharing: Family & Friends	-0.176 (-0.708)	-0.000 (-0.002)	-0.006 (-0.577)	0.164 (0.703)			

Heterogeneity analysis

Table 8: Results from mixed logit models with interactions in preference space (robust z-statistics)

	Sufficient funds (dum)	Eq. hh income	Age (cont.)	Above-average electricity consumption p.c.	EV ownership	Heat pump	Undecided
Purchase PV	1.035*** (2.617)	0.109 (0.855)	-0.044*** (-2.754)	-0.635* (-1.711)	-2.217*** (-4.267)	-1.132 (-1.124)	
Purchase PV + battery	1.719*** (4.353)	0.226** (1.971)	-0.042** (-2.464)	-0.496 (-1.357)	-0.699 (-1.073)	0.199 (0.232)	
Rent-to-own PV	-0.241 (-0.536)	-0.057 (-0.362)	-0.046** (-2.233)	-0.277 (-0.627)	-1.397** (-2.009)	-1.951** (-2.302)	
Rent-to-own PV + battery	-0.507 (-0.975)	0.041 (0.256)	-0.050** (-2.258)	0.381 (0.821)	0.524 (0.714)	0.507 (0.462)	
Energy sharing: Regional	0.101 (0.446)	0.009 (0.122)	-0.000 (-0.051)	0.306 (1.418)	1.066*** (2.765)	-0.043 (-0.102)	
Energy sharing: Family & Friends	-0.176 (-0.708)	-0.000 (-0.002)	-0.006 (-0.577)	0.164 (0.703)	1.082*** (2.590)	0.051 (0.096)	

Heterogeneity analysis

Table 9: Results from mixed logit models with interactions in preference space (robust z-statistics)

	Sufficient funds (dum)	Eq. hh income	Age (cont.)	Above-average electricity consumption p.c.	EV ownership	Heat pump	Undecided
Purchase PV	1.035*** (2.617)	0.109 (0.855)	-0.044*** (-2.754)	-0.635* (-1.711)	-2.217*** (-4.267)	-1.132 (-1.124)	-0.130 (-0.331)
Purchase PV + battery	1.719*** (4.353)	0.226** (1.971)	-0.042** (-2.464)	-0.496 (-1.357)	-0.699 (-1.073)	0.199 (0.232)	-1.540*** (-4.190)
Rent-to-own PV	-0.241 (-0.536)	-0.057 (-0.362)	-0.046** (-2.233)	-0.277 (-0.627)	-1.397** (-2.009)	-1.951** (-2.302)	1.061** (2.248)
Rent-to-own PV + battery	-0.507 (-0.975)	0.041 (0.256)	-0.050** (-2.258)	0.381 (0.821)	0.524 (0.714)	0.507 (0.462)	0.504 (0.997)
Energy sharing: Regional	0.101 (0.446)	0.009 (0.122)	-0.000 (-0.051)	0.306 (1.418)	1.066*** (2.765)	-0.043 (-0.102)	0.024 (0.106)
Energy sharing: Family & Friends	-0.176 (-0.708)	-0.000 (-0.002)	-0.006 (-0.577)	0.164 (0.703)	1.082*** (2.590)	0.051 (0.096)	-0.272 (-1.096)