HOMEOWNERS PREFERENCES FOR BIOSOLAR GREEN ROOFS

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Overview

We investigate homeowners' preferences regarding biosolar green roofs, which combine solar panels and vegetation. Our empirical results, based on a discrete choice experiment (DCE) answered by almost 550 respondents from the cantons of Geneva and Vaud (Switzerland), show that rooftop vegetation is only moderately accepted. Both low and high levels of vegetation are in fact disliked and receive a negative willingness-to-pay (WTP). Another important finding is the difference between horizontal and vertical solar panels. Everything else being constant, it appears that WTP for horizontal panels is CHF 5,000 higher than for vertical panels. Considering vertical panels' important technical advantages for the grid, it appears relevant to design policies to efficiently promote this technology.

Methods

We designed a survey structured in three main sections: respondent screening and preparatory questions, discrete choice experiment (DCE), and follow-up questions on attitudes and socio-demographic variables. The survey was fielded in collaboration with the panel-provider *Innofact* from late August to mid-September 2023. We targeted homeowners residing in the cantons of Geneva and Vaud (Switzerland) with a minimum of 500 complete answers.

In the DCE, participants were requested to express their preferences among two alternatives described by four attributes: vegetation, type of solar panels, electricity production and installation costs (see detailed list of attributes and levels in Table 1). It was also possible to opt-out, i.e., reject both of the investment alternatives. To create the experimental design, we used a "D-efficiency" algorithm (Hole, 2017) and retained 24 situations divided into 6 blocks, so that each participant answered 4 choice tasks. The design was imported in the survey software Qualtrics using the methodology proposed by Weber (2021). Both house and flat owners were included in the sample, and the latter were instructed to consider that the situation describes their individual contribution to a larger collective investment in their building. Note that we also tailored the levels of electricity production and installation costs using a weighting coefficient based on the size of the respondent's accommodation.

Table 1: Attributes and levels in the DCE

Attributes	**Levels**
Vegetation	{non-existent; sparse; average; abundant}
Type of solar panels	{non-existent; horizontal; vertical}
Electricity production (kWh)	{0; 5,400; 9,500; 13,500} × λ
Installation costs (CHF)	{4,200; 11,200; 15,600; 24,700; 33,900} × λ

Notes: Electricity production is 0 only when the proposed installation does not include solar panels. Costs are CHF 4,200 only when the proposed installation does not include solar panels. Current exchange rate is about 1 CHF for 1 EUR or 1 USD. λ is a coefficient used to tailor electricity production and installation costs to the floor area of the respondents' accommodation: 0.8/1.0/1.2 for surface areas respectively ≤60 / (60;90] / >90 m^2.

In order to investigate the stated preferences of households regarding BSGRs, our econometric strategy is based on McFadden's (1974) random utility theory. Our sample consists of $N = 549$ homeowners who make a choice between $J = 3$ alternatives in $T = 4$ choice sets. By choosing alternative j in choice set t, homeowner n obtains utility level $U_{njt} = \beta_n' x_{njt} + ASC_{SQ} + \varepsilon_{njt}$. We estimate both conditional logit models, where the coefficients for alternative-specific attributes are assumed to be constant ($\beta_n = \beta$ for all n), and mixed logit models to relax the Independence of Irrelevant Alternatives (IIA) assumption.

Results

We estimate the attributes' WTP using logit models. For vegetation, we find negative WTP both for sparse and abundant vegetation, while WTP for average vegetation is estimated at CHF 1,350. Our findings therefore imply that

homeowners are only willing to consider green roofs alongside solar panels if the vegetation is cost-effective and low-maintenance. However, BSGRs with only a minimal vegetation do not appear interesting and those with abundant vegetation might be considered as entailing too much maintenance. Another interesting and important result is the gap between vertical and horizontal solar panels. We find a CHF 5,000 difference in favor of horizontal solar panels with respect to vertical panels, whose WTP are estimated respectively at CHF 22,000 and CHF 17,000. The difference can stem from the fact that respondents are certainly more familiar with horizontal panels than with vertical ones. The fact that vertical panels are more visible and considered less aesthetic than horizontal panels may also play a role. Concerning the WTP for electricity production, we find that for each kWh, respondents are willing to pay CHF 1.4. These results can appear particularly large with respect to the average price of CHF 0.32 in 2024 in Switzerland (ElCom). On the other hand, it can illustrate the respondent's aspiration for more autonomy or "self-reliance" (Mamkherzri et al., 2020).

We further investigate the influence of some respondents' characteristics on their investment decisions, namely age, pro-environmental attitudes and associative participation. Respondent's age appears to negatively influence the likelihood of choosing to invest (versus opt-out), suggesting that older individuals may struggle to perceive the return on investment for BSGRs. As expected, pro-environmental attitudes and participation in associations both exert a positive impact on the probability of respondents installing a BSGR in their home.

We finally examine the interaction between several attributes. While the estimated coefficients for electricity production and installation costs remain very similar across the types of panels, we observe important differences for vegetation levels. It appears that respondents are not interested in investing in green roofs if solar panels are not considered. Interestingly, the interaction terms between an average vegetation and vertical solar panels has a positive and highly significant coefficient albeit the coefficient for vertical panels alone is not significant.

Conclusions

Drawing from a sample of 549 homeowners, we investigate the preferences for biosolar green roofs. In particular, we find that vertical solar panels are less valued than horizontal ones, everything else being constant. Considering the benefits offered by vertical panels (Jouttijärvi et al., 2023), it therefore seems important to design mechanisms that encourage their adoption. Because of the quick diffusion of residential PV, relying almost exclusively on horizontal panels, electricity production peaks around the middle of the day and creates grid issues. Vertical panels offer an interesting and complementary alternative by producing electricity earlier in the morning and later in the afternoon, a shape that is better alined with consumption profiles of residential electricity. Varying feed-in tariffs depending on the time of day might therefore be seriously considered. Letting feed-in tariffs fluctuate with supply and demand would favor vertical panels while horizonal ones would produce mostly when market price is low. Offering larger subsidies to vertical panels would also make sense considering they deliver external benefits for the grid maintenance and stability.

Another advantage of vertical panels is their complementarity with green roofs, which offer benefits not only for building occupants (better insulation), but also in environmental terms (biodiversity, reduction of the "heat island" effect). However, this dual installation requires a combination of skills that are rarely found together. Better synergies between the two groups of occupations, training and combined subsidies for both PV and vegetation might therefore be considered to boost the installation of biosolar green roofs.

References

Hole, A. (2017). Dcreate: Stata module to create efficient designs for discrete choice experiments.

Jouttijärvi, S., Thorning, J., Manni, M., Huerta, H., Ranta, S., Di Sabatino, M., Lobaccaro, G., and Miettunen, K. (2023). A comprehensive methodological workflow to maximize solar energy in low-voltage grids: A case study of vertical bifacial panels in nordic conditions. Solar Energy, 262:111819.

Mamkhezri, J., Thacher, J., and Chermak, J. (2020). Consumer preferences for solar energy: A choice experiment study. The Energy Journal, 41(5):157–184.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In Zarembka, P., editor, Frontiers in Econometrics, pages 105–142. Academic Press, New York.

Weber, S. (2021). A step-by-step procedure to implement discrete choice experiments in Qualtrics. Social Science Computer Review, 39(5):903–921.