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Red is the new blue – The role of color, building integration and country-of-origin in homeowners' preferences for residential photovoltaics

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ABSTRACT

The wider diffusion of solar photovoltaics (PV) is crucial to lower the environmental impact of the residential sector, which is responsible for a large share of energy consumption in many industrialized countries, including Switzerland. By conducting an adaptive choice-based conjoint (ACBC) with a representative sample of Swiss homeowners planning to undertake a roof renovation project, we investigate the extent to which financial and non-financial factors drive homeowners' preferences for PV in Switzerland. We reveal that the color and country of origin of the PV modules are the main drivers for increasing share of preference for PV. In addition, we estimate the price premium that homeowners are willing to pay for building-integrated PV (BIPV) versus rack-mounted PV. We find a premium in willingness to pay of 21.79% for a roof with a BIPV installation in comparison with a rack-mounted PV installation. We further show that an increase in revenues from electricity sales (e.g. via feed-in tariffs), when transparently disclosed over an aggregated time frame, would be almost equally effective in spurring demand for PV as a decrease of initial investment costs (e.g. via one-off investment grants). Implications for energy policy and marketing are discussed.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) contends that the extremely likely[1] dominant cause of the observed global warming since the mid-twentieth century is, together with other anthropogenic drivers, anthropogenic greenhouse gas emissions [1]. The urgency of climate change, the pressure on policy makers from international climate negotiations and civil society, and the prospect of greater independence of energy imports have provoked political support and unprecedented growth of renewable energy technologies globally. Meanwhile, renewables are the second-largest contributor to global electricity production [2]. Though still representing a small proportion, solar photovoltaics (PV) have by far the fastest annual growth rates [2].

The wider diffusion of PV is particularly crucial to lower the environmental impact of the residential sector, which is responsible for a large share (approximately 31%) of total final energy consumption in Switzerland [3]. PV in the residential area is commonly rack-mounted on top of an established building (building-attached PV), whereas PV systems integrated into the shell of a building, called building-integrated PV (BIPV), represent only a niche market so far [4]. However, BIPV provide the opportunity for a more upscale architectural design, as they are an integral construction element of a building. BIPV can avoid disruptive visible changes in a building's appearance, while also serving as a new architectural design element with increased aesthetical value for homeowners. Given the many benefits of BIPV, market analysts therefore foresee enormous growth potential in the global BIPV market in the future [5–9].

The contribution of this study is threefold:

1. First, given that BIPV provides the opportunity for a more upscale architectural design than traditional rack-mounted PV plants, we aim to identify, by use of an adaptive choice-based conjoint (ACBC) survey, whether and how much more Swiss residential home owners planning to undergo a roof retrofit are willing to pay for a roof retrofit with a BIPV plant installed than for a roof retrofit with a separate rack-mounted PV plant installed on top.
2. Second, we are interested in what factors, including financial and non-financial, might drive preferences for solar PV among residential homeowners in Switzerland. For this purpose, we perform a series of sensitivity runs in which we change the level

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[1] The term *extremely likely* has been used to indicate the likelihood of 95%–100% of the outcome [1].

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Table 1
Attributes and attribute levels used in the ACBC.

Attribute	Attribute levels		
Roof type (+ base price)	Standard roof/no PV (+ 15,000 CHF)	Rack-mounted PV (+ 40,000 CHF)	BIPV (+ 40,000 CHF)
Color of the PV plant/roof	Blue	Red	Black
Origin of PV panels	China	Germany	Switzerland
Investment costs	Depending on the roof type + random variation to the price shown of −30% to +30%.		
Revenues from electricity sales/reduction in electricity costs over 20 years	−20,000 CHF	−30,000 CHF	−40,000 CHF
Purchase premium	Rebate of 1000 CHF	Participation in an e-car raffle to win a Tesla	Free e-bike

of one factor (e.g. the color of the PV panels) to estimate how such a change influences homeowners' preferences for a PV plant in the course of the next planned roof retrofit project.

3. Third, we also aim to contribute to the energy policy literature on government subsidies. In Switzerland, different kinds of government subsidies are available, including one-off investment grants, which cover a significant part of the cost of an installation, and feed-in tariffs, in which a cost-based price is paid for the renewable electricity supplied to the grid. Previous research on barriers related to PV adoption in Switzerland has shown that homeowners tend to regard upfront investment costs as more important than a reduction in electricity costs from not purchasing electricity from the grid or an increase in earnings from electricity sales to the grid [10]. We therefore imply that consumers would prefer one-off investment grants (which would lower upfront investment costs) to feed-in tariffs (which would increase earnings from selling self-produced electricity to the grid). We investigate whether feed-in tariffs could be made equally effective in spurring demand for PV as one-off grants if future potential earnings from electricity sales would be transparently disclosed over an aggregated time frame of 20 years (a method known as "temporal reframing").

The rest of the paper proceeds as follows: In Section 2, we provide information on the design of the study and discuss our chosen methodological approach. In Section 3, we provide an overview of our empirical findings. Section 4 concludes.

2. Methodological approach

2.1. Structure of the survey

We used Sawtooth Software's module SSI Web to program the survey. The survey consisted of four different sections. First, we placed several screening sections at the beginning of the survey with the aim to identify whether homeowners fulfilled our criteria for eligibility to participate in the survey (see Section 2.5). Second, we continued with the core element of the study, an ACBC, which we describe in detail in Section 2.2. Third, the survey continued by asking respondents about a range of different questions to examine a set of motivators for and barriers to the further diffusion of PV in Switzerland.[2] In the last part of the questionnaire, the respondents answered a set of demographic questions (see Section 2.6).

2.2. ACBC analysis

Homeowners' preferences can be evaluated by analyzing stated or revealed preference data. Given that PV in Switzerland is in the early phase of the diffusion process, appropriate revealed preference data to evaluate consumer preferences and market potential are unavailable for this purpose. We therefore built our empirical approach around a data set of stated preferences, for which we used choice experiments as the methodological approach. This technique is intended to elicit people's preferences for different characteristics, or attributes, of a product in an indirect way. This is done by describing a product or service in terms of different attributes and requiring respondents to evaluate a series of different choice tasks, by performing trade-offs between those attributes [11]. Several studies have applied choice experiments in the area of sustainability and energy [12–23].

We applied an adaptive ACBC method, which adapts the interview flow to the respondents' preferences and is especially appropriate for examining preferences when people make use of non-compensatory decision-making [24,25]. Non-compensatory decision-making takes place when people evaluate alternatives by first excluding the product profiles made up of combinations of attributes and attribute levels that contain characteristics unacceptable to them (e.g. a too high price) and then choosing among the remaining product options in line with those so-called screening rules [24]. Several researchers have used this relatively new methodology in the past few years (e.g., [26–31]).

2.3. Selection of attributes and attribute levels

The ACBC survey asked respondents to evaluate and choose among different roof retrofit options in the context of their planned roof retrofit project. The different roof retrofit options differed depending on whether only standard roof tiles were used for roof covering or the roof also included a roof-top PV system. The different roof retrofit options also differed in the set of characteristics (e.g. investment costs). As a first step in the setup of the ACBC, we chose six different attributes and corresponding attribute levels for inclusion in the study that characterized an individual roof retrofit option. An attribute is a feature of a roof retrofit option (e.g. investment costs) comprising a range of attribute levels of that specific feature (e.g. different price levels). We aimed to select attributes and attribute levels to establish realistic choice scenarios, on the one hand, and to elicit homeowners' preferences for some attribute levels with high relevance for marketing and policy implications, on the other hand. The attributes and attribute levels of the roof options selected for the ACBC are based on consultations with stakeholders, a broad literature review, and a review of product catalogues used for marketing purposes. In addition, a pre-test with experts and colleagues, as well as a small-scale pilot survey with 25 homeowners, confirmed the relevance and suitability of the chosen attributes and levels. Table 1 provides an overview of the six attributes and the corresponding attribute levels used in the ACBC.

We included the attribute "roof type" with three different roof-type options, including the option of a roof with standard roof tiles (the "Standard roof/no PV" option), the option of a roof with roof tiles and a separate rack-mounted PV plant installed on top (the "Rack-mounted PV" option), and the option of a roof with a BIPV plant installed in which the PV panels replace the need for any roof tiles (the "BIPV" option). As a second attribute, we included levels of the color of the PV plant or roof (i.e., blue, red, or black)

[2] We address and report the results of this part of the survey in a separate paper [10].