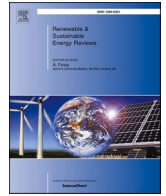




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Keep it local and low-key: Social acceptance of alpine solar power projects

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ABSTRACT

Impressive growth rates of solar photovoltaics (PV) in higher latitudes are raising concerns about seasonal mismatches between demand and supply. Locating utility-scale PV projects in alpine regions with high solar irradiation could help to meet demand during the winter season. However, similar to wind farms, large solar projects change the landscape and may therefore face social acceptance issues. In contrast to the rich literature on wind energy, social acceptance of solar power has received less attention. This paper helps close this gap with the help of a large-scale survey ($N = 1036$) that examines the acceptance of alpine solar projects in Switzerland through choice experiments. In addition to attributes that are well established in the social acceptance literature, such as local ownership, along with both distributional and procedural justice, we also investigate the influence of innovative design elements on acceptance. Our findings suggest that local ownership, as well as colored solar panels that reduce the perceived landscape change may increase social acceptance, implying that projects should be kept local and low-key. We also find that acceptance of alpine solar projects is higher among the affected population than among inhabitants of non-alpine regions.

1. Introduction

Among the renewable energy technologies, solar energy has one of the highest growth rates, and could therefore contribute substantially to reducing dependence on fossil fuels [1]. Initiatives designed to increase the proportion of renewable energies in the national energy mix have been introduced in many countries [2]. One concern with electricity systems relying on a high share of renewables is their ability to match demand and supply at any given time. In densely populated areas of higher latitudes, such as Central Europe, the Northern US or Canada, a particular concern is the seasonality of solar power generation, which peaks in the summer, whereas electricity demand tends to be high in the winter. One way of alleviating this mismatch is to build up a diversified portfolio of wind and solar power [3–6], as there tends to be more wind during the winter half-year [7]. However, despite being widely supported at the national level [8,9], the growth of wind power has recently been slowing down in various countries due to local acceptance issues [10–12]. Apart from diversification across technologies, geographical diversification is another possibility to address seasonality. For solar power in particular, locating utility-scale projects in alpine areas could allow for an increased share of electricity generation during the winter half-year. Alpine regions benefit from up to 50% higher levels of irradiation, less fog, lower temperatures and greater snow reflection

[13–15] than lowland areas, making them a promising location for solar PV projects. At the same time, utility scale projects can have an impact on the landscape, which may raise social acceptance issues. As landscape is perceived to be one of the most important elements of leisure and tourism attractions, sensitivity is usually high regarding alterations to the former in alpine regions [16]. While a variety of attributes that modify the social acceptance of wind energy projects have been investigated recently [17–20], social acceptance of utility-scale solar photovoltaics has received less attention [13,21,22].

Accordingly, the goal of the present research was to highlight the attributes as well as their levels that determine the social acceptance of solar projects in alpine regions. To this end, we implemented a choice experiment capable of testing the combined influence of a number of attributes: environmental impact, distributional and procedural justice, local ownership, and design. This resulted in the following two main research questions:

- 1) What are the attributes that determine the social acceptance of utility-scale solar PV projects in alpine regions?
- 2) Which attribute levels can increase the local acceptance of a solar PV project?

The following sections of this research paper are structured thus: The

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next section provides a review and discussion of literature associated with the social acceptance of renewable energies, focusing on solar PV. Our hypotheses are drawn up on this basis. The design of the research and the types of choice attributes and levels are described in Section 3, along with a presentation of the analytical sample. Section 4 elucidates the outcomes of the choice experiment in relation to the hypotheses. Section 5 concludes with policy implications and recommendations targeted at project developers. This section includes a discussion of the limitations of the paper and contains suggestions for further research.

2. Literature review

2.1. Social acceptance of renewable energy

An increasing amount of research is being dedicated to the topic of social acceptance of renewable energy [23,24]. Several studies have found very high overall acceptance for different renewable energies [8, 25]. A notably high level of support for ambitious national renewable energy targets has also been identified [26]. Moreover, among the variety of renewable energy technologies, solar PV may be distinguished by its more positive public perception and acceptance [25]. Solar PV is also widely associated with positive features such as environmental protection and job creation [27]. Cousse & Wüstenhagen [28] found that high social acceptance levels for solar PV uphold when moving from support for the technology at an international (88%) to a national level (85%) in Switzerland, whereas the same measure drops from 70% to 57% for wind energy. In the same survey, 66% of respondents said they would be proud to see solar PV projects being installed in their vicinity, more than twice as many as for wind energy (28%). In line with earlier work that claims that solar PV is unique among renewable energy technologies in relation to the level of social acceptance, we formulate the following Hypothesis:

Hypothesis 1. Solar PV projects in alpine regions are associated with a high overall level of acceptance.

2.2. From socio-political to local acceptance of renewable energies

High overall levels of socio-political acceptance are necessary but inadequate for the successful deployment of energy technologies. A crucial question is to what extent this translates to high levels of local acceptance [23,29]. In the case of wind energy, several studies have found high levels of socio-political acceptance [30,31], although landscape-related concerns are just one of the issues that affect the public acceptance of wind energy projects at the local level [10]. These issues of resistance may directly translate into major project delays or even abandoned projects [32,33]. Aitchison et al. (2010) identify a high level of sensitivity regarding landscape changes for alpine regions, given their reliance on tourism. To implement renewable energy projects in such sensitive regions, project developers and local governments must establish a clear understanding of the possible negative effects of such projects and identify appropriate mitigation measures.

One of the elements that has been shown to moderate the effects of landscape changes on social acceptance, is the level of procedural and distributional justice [19,33–35], i.e. fair decision processes and a fair distribution of the project's costs and benefits. The literature shows that a high degree of distributional as well as procedural justice can have a positive influence on the social acceptance of a renewable energy project, for example, in relation to the effect of the level of procedural justice in relation to wind energy projects. Jami and Walsh [18]; Firestone et al. [19] and Dwyer and Bidwell [20] conclude that greater involvement of the public (e.g. more consultation) is required at the stage of project development, while concerning the social acceptance of projects, Warren and McFadyen (2010) [36] show that community ownership can reduce dispreferences and simultaneously strengthen favourable attitudes towards wind power. Following previous work that suggests that a

high degree of procedural and distributional justice are important for mitigating the negative effects of renewable energy technologies, we test the following hypotheses:

Hypothesis 2a. Distributional justice increases social acceptance of solar PV projects in alpine regions.

Hypothesis 2b. Procedural justice increases social acceptance of solar PV projects in alpine regions.

2.3. The influence of design on social acceptance

Of the negative effects of renewable energy technologies, one of the most often cited is visual impact [30]. In the context of wind energy, various studies have identified a moderating influence of factors such as design, size, and color on social acceptance [37–39], although the results of other studies have been inconclusive in this regard [40–42]. Sánchez-Pantoja et al. [43] review the literature on aesthetic impacts of solar energy systems and point to factors like color, glare and texture. For residential PV systems in particular, Hille et al. [44] find that adjusting the color to the surroundings can increase acceptance. More specifically, they found that Swiss homeowners would prefer panels that are red (which is the prevalent color of roof tiles in Switzerland) over conventional blue panels. Similarly, Jolissaint et al. [45] discuss the advantages of colored panels for smooth integration of solar PV into the built environment, and Bao et al. [46] identify a preference among affluent homeowners for low-visibility solar systems.

A second, more novel way of addressing the landscape effects of PV projects is to use solar art. Solar art is gaining popularity as a new means of providing design elements for solar PV projects [47]. Innovative artistic designs include utility-scale solar projects in China in the shape of a giant panda [48], or the concept of a solar tree [49]. One emerging stream of research that spans architecture and urban planning suggests that context sensitivity may increase the aesthetic quality of PV installations, and that designing solar landscapes is more than just an engineering task [43,50]. Introducing solar art could address visual concerns and increase the overall acceptance of solar PV projects in alpine regions. We therefore state the following hypotheses:

Hypothesis 3a. Adjusting the color of solar panels to the surroundings increases social acceptance of PV projects in alpine regions.

Hypothesis 3b. Artistic design elements increase social acceptance of PV projects in alpine regions.

3. Methodology and data

3.1. Methodology

A choice experiment was undertaken with Swiss residents in order to respond to our research questions. An alpine country with an ambitious national energy strategy, Switzerland has one of the most rapidly growing markets in Europe for solar energy, but past growth has mainly focused on rooftop PV on residential and commercial buildings. Given the slow pace of wind energy deployment, the country is in need of new solutions for seasonal diversification of its renewable energy supply. In combination with a direct democratic setting, this makes it an ideal candidate to study social acceptance of solar PV projects in alpine regions. Because of its federalist political system, large Swiss renewable energy projects are subject to social acceptance issues on national, regional (cantonal) and local levels. We therefore drew on a nationwide sample (N = 1036), while controlling for respondents' place of residence in order to investigate any differences between inhabitants of alpine regions and respondents residing elsewhere.

Choice experiments (CE), which have become more popular in energy and environmental economics research in the last few years (e.g. Ref. [51–54]), originate from market research and are a well-established method of assessing the preferences of consumers. They are often used in

the process of developing new products when real purchasing behavior cannot be observed [55]. The use of CE compared to traditional valuation methods is associated with several advantages: respondents are presented with realistic choice situations, while the indirect nature of preference surveying reduces the bias created by asking survey respondents to state their preferences directly [56]. The latter factor is especially important within the context of the energy and environmental field due to the analytical challenge of handling direct survey responses that are affected by social desirability bias. The most widely used type of CE, choice-based conjoint analysis (CBC), was chosen [57] for use in the present study.

3.2. Survey design and variables

The survey design included four parts: (1) general introduction and project description, (2) general social acceptance measurement, (3) choice experiment, and (4) control and socio-demographic variables. In the first part, participants were introduced to the topic and given information about solar PV in alpine regions, including information about the size of the hypothetical project, the annual electricity production, and the potential location of the project, as well as information about the efficiency of solar PV projects in alpine regions (Appendix A). A diagram was included to help inform and illustrate to respondents the details of the project [58] (Appendix B).

In a second section, respondents were asked to state their overall level of acceptance of the (hypothetical) solar PV project located in the Swiss alpine region. The description and visualization of the hypothetical alpine solar project used in the survey is attached in Appendix B. To measure the level of acceptance, participants had to indicate to what extent they agree with the following statement: "I would accept solar installations in alpine regions (as described above)", with the term "as described above" referring to the description of the hypothetical alpine solar project. Responses were indicated and measured using a 5-Point Likert scale. Similar approaches to measure general acceptance were also used in other research papers such as Tabi and Wüstenhagen [59] or Vuichard et al. [9].

In the third part, a choice experiment was set up to identify respondents' preferences for a variety of scenarios with different attributes and levels (see Table 1), which were based on a literature review and a previously conducted pre-test with industry experts. Subsequently, each participant responded to eight choice tasks, in each of which they had to choose from four scenario options – three versions of the hypothetical alpine solar PV project, and a none option (which could be selected if none of the proposed projects was acceptable to the participant). The choice task was formulated as follows: "Imagine you could choose between three solar PV projects in alpine regions of Switzerland (ground-mounted projects that would produce 1.5 gigawatt h per year in the vicinity of existing infrastructure – as outlined before). Please select your preferred project (by clicking). The projects are different in the following ways..." The different attributes and levels used in the choice experiment were as follows:

- The first attribute, "design", refers to the different design options of the solar PV project. Levels ranged between conventional blue solar panels to green solar panels¹ which blend better into the landscape, to art elements: a solar PV system designed in the shape and color of a

¹ There are different technological options to change the color of solar PV panels. One recently commercialized approach is to apply colored nanotechnology films to absorb particular wavelengths of sunlight (see for example solaxess.ch). This technology leads to only minor reductions in conversion efficiency (approx. 10%).

Table 1

Attributes and levels of alpine solar PV projects presented in the choice experiment.

Attributes	Explanation	Levels
Design of the solar PV project	Design of the solar PV project with conventional design, color variations, or artistic elements	(1) conventional solar panels (2) green solar panels (3) artistic element: animal design (Capricorn) (4) artistic element: Swiss flag design
Ownership	Developer responsible for building and/or operating solar PV project	(1) international utility (2) local utility (3) combination of local utility and inhabitants (4) farmers cooperation
Ecological impact	Impacts on the surrounding ecosystem (flora and fauna)	(1) medium (2) small (3) almost none (4) net positive
Distributional justice	Extent to which solar PV project benefits are shared	(1) hardly any local financial benefits (2) compensation for private landowner (5000 CHF/per year) (3) individual participation in the project through financial investment and dividend payments (4) compensation to municipality via a solar tax (15,000 CHF/per year)
Procedural justice	Public involvement in solar PV project at stages of decision and planning	(1) legally required participation (2) public information events (3) co-determining the design of the solar PV project (4) co-determining the design, size, and location of the solar PV project

capricorn² or the Swiss flag.³ By using Sawtooth's mouseover feature, participants could see illustrative pictures of each of the design options (Appendix C).

- The second attribute, "ownership", refers to the project developer. Its four levels ranged from a foreign energy company to a local utility (with or without citizen investors), to a farmers' cooperation. We used this attribute to test for the effect of local (co-) ownership on acceptance.
- The third attribute, "ecological impact", described the solar PV project's potential damage to local fauna and flora [60]. The main adverse ecological impacts of solar PV projects in alpine regions are damage to grass roots when installing the panels, as well as the construction of access roads to the project site. On the other hand, there may also be positive ecological impacts of ground-mounted solar projects such as erosion prevention, improved soil fertility, habitat for species, and an increase in water-use efficiency [61]. Since the survey was intended to be understood by lay respondents, the complexity of the former effects was reduced by including simplified references to them, associated with levels that varied between net positive, almost none, small and medium ecological impact.
- The fourth attribute, "distributional justice", described different options of distributing the project's economic benefits. Regarding local

² China has already built several solar power projects in the shape of giant pandas – other countries have also planned to build solar power projects in the shape of animals [48]. We chose the capricorn as it is part of the flag of the canton of Graubünden, one of the largest alpine cantons in Switzerland.

³ Large (textile) Swiss flags on alpine slopes are a common sight in Switzerland and are widely accepted [83].

taxation, unlike the water resource tax associated with hydropower [59], Swiss legislation does not require utility-scale solar PV project operators to financially (or otherwise) compensate local community stakeholders (residents, etc.). However, the operator may introduce a voluntary community benefit scheme ("solar resource tax"). This factor was thus included in the choice experiment as one level (defined as 1 ct./kWh payable to the municipality, equivalent to 15,000 CHF per year assuming 1500 full load hours and 1 MW of installed capacity). Additional levels included the opportunity for individuals to financially participate in the solar PV project and benefit from dividend payments, compensation for individual land-owners, or hardly any local financial benefits.

- The fifth and final attribute, "procedural justice"⁴, investigated preferences for public involvement in the project's planning phase. The degree of involvement ranged from only legally required participation, to public information events, to citizens co-determining the design, and potentially also the size and location of the project.

The fourth and final part of the survey consisted of control and socio-demographic variables about our respondents. Control variables included *nature bonding* (people's attachment to the alpine region) based on a four-item scale which is part of the concept of place attachment based on Raymond et al. [62]; and a ten-item scale to measure *ethically minded consumer behavior* (EMCB) based on Sudbury-Riley & Kohlbacher [63]. Both *nature bonding* as well as *EMCB* were measured using a five-point Likert scale. Additionally, we asked participants if the municipality they live in would potentially be suited to an alpine solar PV project as described in the survey introduction text (coded as 1 = yes, 2 = no). Socio-demographic variables included age, gender (1 = male, 2 = female), education, gross household income, and political attitude (based on Swiss party preference indication, which was classified into three categories, see Table 2).

3.3. Data analysis

The CBC approach derives the preferences of surveyed respondents in relation to different attributes of hypothetical solar PV projects. It is closest to a real decision making situation and best suited to reveal real preferences for unfamiliar or new products or projects (see also Tabi & Wüstenhagen, 2015 [64]; or [65]). Further, compared to questions measuring self-reported answers, the CBC approach is superior in terms of revealing the real preferences of participants for each of the attributes and corresponding levels by creating trade-offs between the attributes within the presented choice tasks. From the point of view of the participants, the various project combinations have certain advantages and disadvantages when they are evaluated subjectively. This leads to the fact that the participants have to weigh the importance of the project attributes relatively against each other and thus become aware of the actual importance of the individual project attributes. Consequently, results of a CBC approach have lower self-reporting or social desirability biases (Albers et al., 2009; [66]).

The project attributes used (see Table 1) were independent of each other in order to generate an undistorted estimation of respondents' preferences. Each choice task elicits the respondent's willingness to accept tradeoffs among more or less desired project attributes, the levels of which vary randomly depending on the choice task. Each of the 1036 respondents evaluated eight choice tasks, leading to a total of 8288 experimental choices. Choice data were analyzed in two stages with the use of a hierarchical Bayesian (HB) estimation [67] in the following way: The HB estimate initially sorted the attributes of the hypothetical solar PV project into a ranked list of "importances" (expressed as

⁴ This attribute is similarly operationalized as in Refs. [59]; who examined the influence of procedural justice on social acceptance of hydropower projects.

Table 2

Parameters of sample in relation to Swiss population.

	Total sample (n = 1036)	Swiss population ^d
Age ^a 18-29	17.9%	16%
Age 30-44	25.6%	26%
Age 45-59	27.3%	28%
Age 60+	29.2%	30%
Men/Women	49%/51%	49%/51%
Political Attitude ^b : Conservative	44.4%	45.8%
Political Attitude ^b : Centrist	21.2%	22.2%
Political Attitude ^b : Left-wing	26.4%	25.9%
Income: Low ^c	29.7%	29.4%
Income: Mid ^c	42.8%	44.9%
Income: High ^c	27.5%	22.3%
Region: French-speaking Switzerland	25.3%	25%
Region: Alps and Pre-Alps	19.6%	24%
Region: Central-West	25.8%	22%
Region: Central-East	29.3%	29%

^a Respondents younger than 18 years old were excluded (the age values specified by the Swiss Federal Office of Statistics also exclude this age group).

^b Political attitude was determined in relation to the outcome of voting in the 2015 Swiss national election. Eight different party preferences were consolidated into the following broad groups of political attitudes: conservative (SVP, FDP), centrist (CVP, BDP, GLP, EVP) and left-wing (SP, Green). The category "other political party" categorized 8% of the total sample (representing a preference for a party (ies) not represented in the Swiss parliament).

^c Classified as gross monthly income per household, with the five reported income classes merged into three income groups: Low Income = less than 6000 CHF, Middle Income = 6000–12,000 CHF, High Income = above 12,000 CHF.

^d Swiss Federal Office of Statistics (BFS) (2018) [84];: Seat distribution.

percentages). The latter indicate the relative strength of preference of a project attribute compared to others in the set [68]. We then calculated the part-worth utilities associated with each attribute level, attributing a negative sign to the parameter estimates for levels that respondents were reluctant to accept. The result was a set of regression coefficients that approximated participants' part-worth utilities for attribute levels.

3.4. Sample

Respondents were selected from an actively recruited online consumer panel containing more than 100,000 individuals that was constructed by a professional market research company.⁵ Data collection took place between October 6 and October 20, 2019. The original sample included 1189 participants with an overall drop-out rate of 12.9%, giving a final sample of 1036 participants. This sample was deemed representative of the population of Switzerland in terms of age, gender, income, political preference (party), and geographical area (see Table 2). The survey was translated into French and German, the two main official national languages. Because Italian- and Rhaeto-Romanic-speaking parts of Switzerland account for only 8.1% (0.5%) of the Swiss population (respectively), they were omitted [69].

4. Results & analysis

4.1. General acceptance level

Fig. 1 illustrates the overall acceptance level for the overall sample (n = 1036): Sixty-four percent of respondents agreed or fully agreed that they would accept a solar PV project in an alpine region, whereas only 14% of the participants stated that they would not be willing to accept such a project.

A segmented analysis revealed further insights: participants living in

⁵ Intervista: <https://www.intervista.ch/panel/?lang=en>.

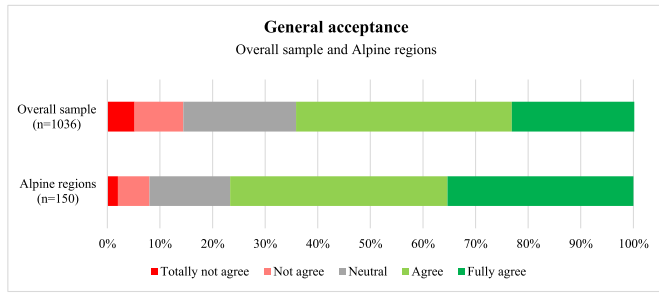


Fig. 1. General acceptance for alpine solar PV projects: overall sample and alpine communities.

alpine regions (who would be directly affected by such solar PV projects) indicated a significantly higher overall acceptance level compared to participants who were not (i.e. the rest of Switzerland) (see Fig. 1). The mean acceptance value for participants living in alpine regions was 4.02 ($SD = 0.97$, $N = 150$) compared to 3.63 ($SD = 1.09$, $N = 886$) for the rest of Switzerland ($p < 0.000$, based on one factor ANOVA). Seventy-seven percent of all respondents living in alpine regions agree or fully agree that they would accept an alpine solar PV project in their region, whereas only 8% would not or absolutely not accept such a project.

Similar to Walker et al. [70] and Tabi & Wüstenhagen [59] we find that political attitude acts as an important predictor of the social acceptance of renewable energy projects (see Fig. 2). Centrists ($m = 3.86$, $SD = 0.99$, $N = 220$) and left-wing voters ($m = 3.90$, $SD = 0.90$, $N = 273$) are significantly ($p < 0.000$, based on a one factor ANOVA, for centrist and for left-wing voters) more willing to accept alpine solar projects than conservative voters ($m = 3.47$, $SD = 1.18$, $N = 460$).

4.2. Influence of socio-demographic and control variables on general acceptance level

To analyze the influence of our control and socio-demographic variables on the general acceptance level of alpine solar PV projects, we ran a linear regression model. The regression model included the dependent variable (general acceptance level) as well as the socio-demographic variables. Table 3 illustrates the outcome (calculated using SPSS):

The regression model reveals the importance of socio-demographic variables in predicting acceptance levels for alpine solar PV projects. Attitudes such as nature-bonding as well as pro-environmental consumption behavior (EMCB) have a significant impact on the general acceptance level. While people with strong feelings about pro-environmental consumption are more likely to accept alpine solar PV projects, people who are strongly attached to nature and want to preserve it as it is are more likely to not accept such projects. Additionally, income and political orientation also have a significant influence on the general acceptance level. Conservative voters are more likely not to accept alpine solar PV projects compared to people who have a centrist or left-wing political orientation. Finally, respondents with a higher income are more likely to reject alpine solar PV projects than those with

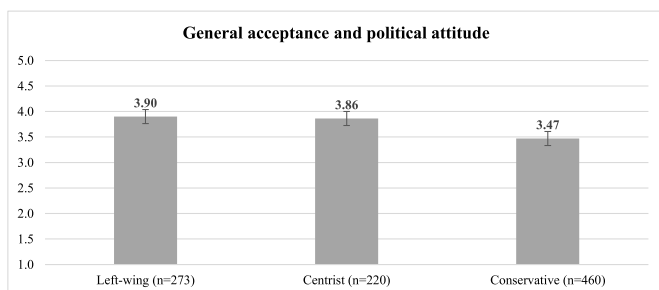


Fig. 2. Political attitude and general acceptance of alpine solar PV projects.

Table 3

Linear regression - SPSS output table.

Variable	B	Standard error	t	F	Sig.
Alpine region ^a	−0.390***	0.093	4.195	17.598	0.000
Nature bonding ^b	−0.163***	0.049	−3.318	11.007	0.001
EMCB ^c	0.250***	0.052	4.811	23.144	0.000
Age ^d	0.001	0.002	0.600	0.360	0.549
Gender ^d	−0.093	0.067	−1.394	1.942	0.164
Income ^d	−0.059**	0.028	−2.120	4.495	0.034
Political attitude ^d	0.136***	0.035	3.873	15.003	0.000
Intercept	3.381***	0.240	14.103	220.490	0.000

*** $p < 0.05$; ** $p < 0.01$, dependent variable = general acceptance.

F-test of total model: $n = 1036$; $F = 11.056$; $df = 7$; $Sig. = 0.000$; R squared = 0.070; Adjusted R squared = 0.064.

^a Coded as 1 = alpine region, 2 = rest of Switzerland.

^b Four-item nature-bonding scale *Cronbach's Alpha* = 0.716 (based on $n = 1036$).

^c Ten-item EMCB scale *Cronbach's Alpha* = 0.905 (based on $n = 1036$).

^d Age in years; Gender (1 = male, 2 = female); Income based on 3 levels, low income = 1, med income = 2, high income = 3 (see Table 2); political attitude coded as 0 = other, 1 = conservative, 2 = centrist, 3 = left-wing (see Table 2).

a lower income.

4.3. Choice experiment: attribute importance and part-worth utilities

Results of the choice experiment were analyzed in Sawtooth using the hierarchical Bayesian (HB) estimation. The average RLH⁶ of the HB model is 0.676 with an average percentage certainty⁷ of 0.718, which indicates good model fit. In terms of attribute importances for the overall sample, the HB estimation shows that “design of the solar PV project” is the most important attribute (36.68%, $SD = 15.18$), followed by (local) ownership (21.00%, $SD = 9.35$). The three other attributes of the alpine solar project, ecological impact (15.60%, $SD = 8.39$), distributional justice (14.19%, $SD = 5.58$) and procedural justice (12.53%, $SD = 5.42$) exhibit similar, and somewhat lower, importance levels.

Additionally, we also compared the average importance levels of the attributes for alpine regions ($n = 150$) to the levels for the rest of Switzerland ($n = 886$). The analysis showed no significant differences

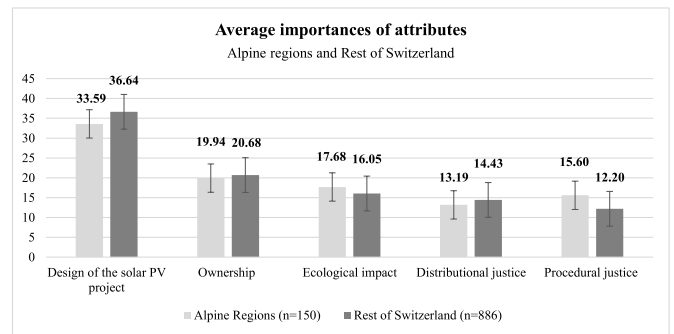


Fig. 3. Average importances of attributes for samples “Alpine regions” and “Rest of Switzerland”.

⁶ The logit equation predicts the probability of choice for each of the alternatives (concepts) in a choice task for each respondent. RLH (Root Likelihood) is the geometric mean of the predicted likelihoods for the concepts the respondent actually chose [85].

⁷ Pct. Cert. (also known as pseudo R-squared) is a related statistical value, but is calculated differently. Its meaning essentially asks, “what percentage of success - between the null prediction and the best possible prediction - were we able to achieve with this model?” [85].

concerning the importances of the different attributes (see Fig. 3). The design attribute remains by far the most important attribute for both samples, followed by the ownership structure and the ecological impact. A difference can be observed with regard to distributional and procedural justice. In Alpine regions, procedural justice is considered to be more important in comparison to distributional justice, whereas in the rest of Switzerland, distributional justice is rated slightly higher compared to procedural justice.

A deeper look at part-worth utilities (for the overall sample) associated with different levels of attributes (Table 4) creates further insight. The design attribute leads to relatively strong reactions, with green panels adjusted to the landscape (score of 75.06) being clearly preferred over conventional panels (20.23). On the other hand, innovative artistic design elements are less well received, with the capricorn-shaped installation (−38.74) scoring relatively higher than the Swiss flag (−56.56). As can be seen from Fig. 4, young respondents are relatively more open to innovative design concepts than old respondents, but the preference for green panels that improve the solar plant's embeddedness in the surroundings is shared across age groups. Furthermore, voters of the national-conservative party are also skeptical towards innovative design elements, but they slightly prefer the installation in the shape of the Swiss flag (−38.59) over the capricorn design (−41.96).

As for the second most important attribute, ownership, the most preferred level is a combination of a local utility with inhabitants (33.93), while an international utility is the least preferred option (−54.65), suggesting that local ownership contributes positively to social acceptance. When it comes to ecological impact, the third most important attribute overall, the direction of the effect is as expected: projects with lower ecological impacts are preferred over projects with higher ecological impact. Fig. 4 shows that young respondents are more sensitive to environmental aspects of the project than older respondents: Among 18-29-year-olds, the preference for a project with net positive

ecological impact (45.38) is twice as strong as among 60+year-olds (23.98). In terms of the attribute distributional justice, the key insight is that sharing the financial benefits with the local population increases social acceptance of an alpine solar PV project. Which kind of benefit sharing is pursued has less of an influence, as there is only a slight preference for direct financial participation models compared to collective participation via the solar resource tax. Procedural justice turns out to be relatively less important, but the effect is also as expected: offering additional participation options beyond the legally required minimum has a small, but positive effect on social acceptance of the project. Interestingly, young respondents, in contrast to senior citizens, prefer a public information event over more active, but therefore also more time-consuming forms of participation, such as co-determining the size, location and design of the project. Given the lower openness of the older generation towards innovative design features, this lukewarm willingness of the 18-29-year-olds to show hands-on involvement may represent a barrier towards implementing such new approaches. Finally, the none-option had a score of −81.22, indicating that participants rarely chose this option in the choice task and generally preferred any of the offered three hypothetical solar projects over no project at all, in line with the high levels of acceptance observed in the direct question (see above).

5. Discussion

Using the results and analyses presented above, we can subsequently discuss the hypotheses presented and derive relevant policy implications and recommendations for project developers.

Our first Hypothesis, “Solar PV projects in alpine regions are associated with a high overall level of acceptance” is confirmed. 64% of all participants would accept solar PV projects in alpine regions, resulting in a mean acceptance value of 3.68 ($SD = 1.08$, $N = 1036$). This result supports findings by authors such as Kaenzig et al. [27]; Sütterlin and Siegrist [29]; Plum et al. [71]; and Cousse and Wüstenhagen [28]; who have shown that solar PV has a unique position among renewable energy technologies in terms of social acceptance. It also adds to the findings of Michel et al. [13] who identified a high level of acceptance for alpine solar PV projects on existing infrastructure, such as avalanche barriers. Our results indicate that the acceptance level also remains high when the solar PV project is located in the vicinity of existing infrastructure.

Results from the segmentation analysis produce further interesting insights. Residents of alpine regions, who would be directly affected by the solar PV projects, are more likely to accept such projects compared to people not living in alpine regions. This high level of local acceptance resembles of a PIMBY (Please in My Backyard) more than a NIMBY (Not in My Backyard) effect [72–74], and may be related to the fact that electricity generation with solar PV projects creates a new source of income for alpine regions [14]. Tangible financial benefits have been shown to facilitate local acceptance in a wide range of energy technologies, including nuclear waste repositories [75] and hydropower plants [59], even if their implementation needs to be carefully designed, preferably with the direct participation of the local population as shown in Fig. 3, to avoid unintended side-effects [76]. Additionally, Michel et al. [13] mention the above-average exposure of alpine regions to climate change – awareness of this situation might contribute to the high local acceptance level among residents of alpine regions. There may also be affective factors in place, such as a sense of pride about the solar project [28] contributing positively to local patriotism [64,77].

The implementation of renewable energy projects also has a political component. Our results show that centrist and left-wing voters are significantly more likely to accept an alpine solar PV project compared to conservative voters. Nevertheless, conservative voters also have a total overall acceptance level of $m = 3.47$ on a five-point Likert scale ($SD = 1.18$, $N = 460$). Interestingly, conservative voters who live in alpine regions have a significantly higher overall acceptance level ($m = 3.93$) than conservative voters ($m = 3.39$) living elsewhere. Their level of

Table 4
Results of the HB model estimation – zero-centered part-worth utilities.

	Average utilities (zero-centered diffs)	Standard deviation
Design		
Conventional solar panels	20.23	54.31
Green solar panels	75.06	67.30
Art element: animal design (Capricorn)	−38.74	57.38
Art element: Swiss flag design	−56.56	62.67
Ownership		
International utility	−54.65	38.19
Local utility	19.91	27.00
Combination of local utility and inhabitants	33.93	24.05
Farmers' cooperation	0.81	26.30
Ecological impact		
Medium	−15.68	27.83
Small	−19.87	24.09
Almost none	2.12	18.87
Net positive	33.43	35.05
Distributional justice		
Hardly any local financial benefits	−36.91	21.10
Compensation for private landowner	13.97	22.41
Individual participation in the project	12.21	17.92
Compensation via solar resource tax	10.73	18.00
Procedural justice		
Legally required participation	−28.70	24.26
Public information events	6.14	18.42
Co-determining the design of the project	7.78	18.38
Co-determining the size, location and design	14.78	18.75
None Option	−81.22	192.50

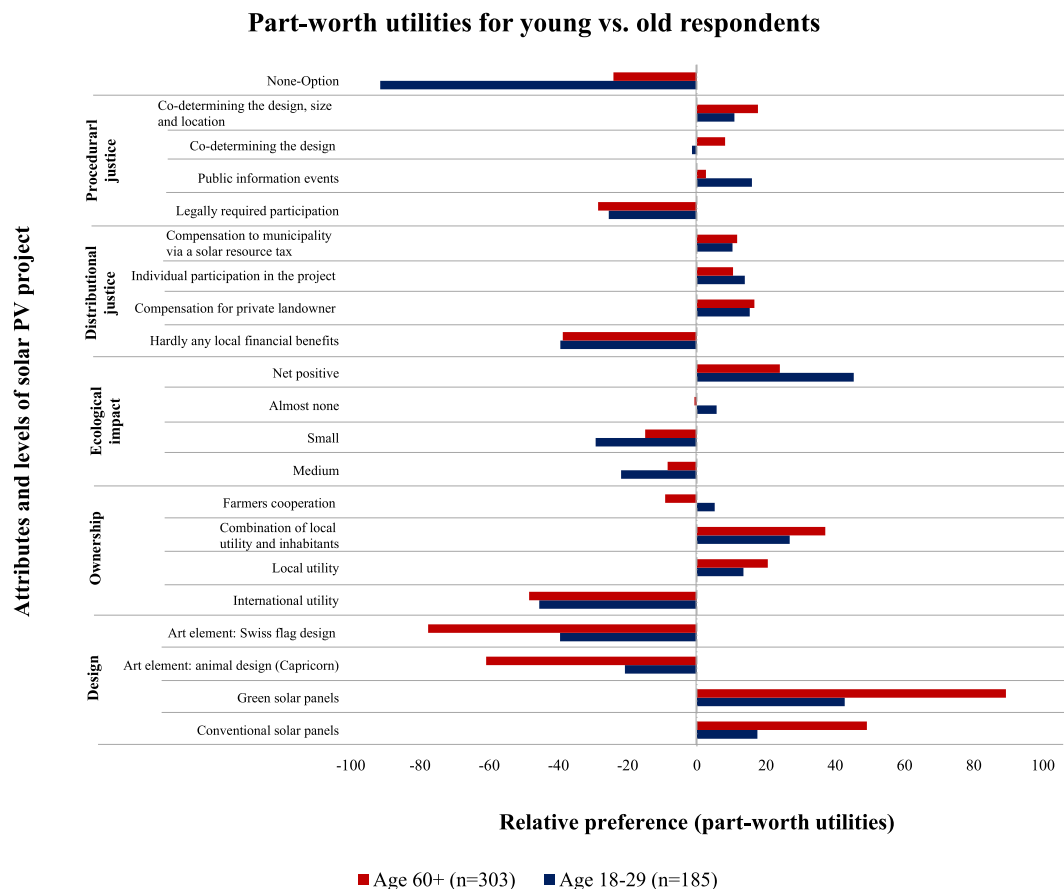


Fig. 4. Part-worth utilities for young vs. old respondents.

acceptance is even higher, although not significantly, than that of left-wing ($m = 3.90$) and centrist voters ($m = 3.86$) not living in alpine regions, which in sum further strengthens our finding concerning the high level of acceptance of solar PV projects in alpine regions, especially at a local level.

Hypothesis 2a, “*Distributional justice increases social acceptance of solar PV projects in alpine regions*” can only partially be confirmed. Findings from the choice experiment suggest that a lack of local benefits decreases the social acceptance of solar projects in relation to the three benefit-sharing levels. This conclusion supports the findings of the literature about the social acceptance of wind energy [17,36,76,78,79] and hydropower [59]. However, distributional justice turned out to be only the fourth most important attribute - this overall picture holds true for the sub sample of the Alpine region, where procedural justice is slightly preferred to distributional justice, but both attributes rank fourth and fifth, respectively. This outcome indicates that other factors are stronger determinants of social acceptance. This may be specific to the Swiss context, where environmental awareness is relatively high, which is reflected in the higher importance of the attribute ecological impact in the results of our choice experiment. Among the different possibilities of local benefit sharing included in our analysis, respondents showed a slight (but not significant) preference for direct financial participation options (compensation for landowner or individual participation in the project through financial investment and dividend payments) over collective financial participation options, operationalized in this research project through a *solar tax* which would benefit the community as a whole.

Similarly, Hypothesis 2b, “*Procedural justice increases social acceptance of solar PV projects in alpine regions*” can only partially be confirmed. Our results show that higher levels of procedural justice correspond to higher levels of social acceptance, but the effect is less

pronounced than for the other attributes. Participants stated a preference for co-determining the size, design, and location of projects (score of 14.78) over all other levels, especially over the lowest level of procedural justice “legally required participation” (score of -28.70). This adds to findings by Devine-Wright [80]; Wolsink [42]; Dimitropoulos and Kontoleon [38] and Lienhoop [81]; who also researched public participation in the planning process of renewable energy projects and identified a demand for greater consultation of the public. However, the HB estimation also reveals that procedural justice is the least important attribute in the overall choice-experiment (12.53%), mirroring the findings of Tabi & Wüstenhagen [59] who, for the case of hydropower, pointed out that this may be due to the fact that Swiss citizens take high levels of procedural justice for granted, given the high number of options that already exist to directly participate. In summary, procedural justice can help to increase the social acceptance of a solar PV project, but above all, developers must get other attributes of the project right, such as a context sensitive design, local ownership, and low ecological impact.

Hypothesis 3a, “*Adjusting the color of solar panels to the surroundings increases social acceptance of PV projects in alpine regions*” can be confirmed. With an importance level of 36.68%, the design of the project is the most important attribute in terms of explaining respondents’ decision to accept one of the proposed alpine solar projects in our choice experiment. The visual appearance of solar PV projects seems to be an important driver of social acceptance. This adds to findings from research on visual impacts of renewable energies, mainly in the context of wind energy. Elements such as the height of turbines of wind energy projects [37] or the proximity of turbines to residential areas [38,82] as well as the specific location of wind parks [39] were identified as important factors determining local acceptance of a project. Looking at part-worth utilities of the levels of the design attribute shows that the

option “green solar panels” (score of 75.06) is strongly preferred over conventional panels (20.23). This confirms the importance of context sensitivity in solar design [43,50] and adds to the findings of Hille et al. [44] who identified a match between the color of solar panels and the surrounding roof as a factor increasing acceptance of rooftop solar among Swiss homeowners. Adjusting the color of solar panels to the natural surroundings may also be a way of addressing the concerns of people who feel strong bonds to nature and might otherwise be opposed to utility-scale projects in the mountains.

Hypothesis 3b, “Artistic design elements increase social acceptance of solar PV projects in alpine regions” cannot be confirmed based on the analysis presented in this paper. Our exploratory approach to suggest a novel element of solar art was not well received among respondents. The HB estimation of the part-worth utilities revealed that including innovative solar art elements did not have the intended effect: both an installation that resembled a Swiss flag (score of −56.56) as well as the capricorn design (−38.74) reduced the likelihood of the project being accepted compared to a conventional design. This is somewhat in contrast to the positive media coverage that pilot projects of solar art have received, such as the panda-shaped utility-scale solar projects [48] or installations of “solar trees” [49]. One possible explanation is the novelty of this idea to respondents – after all, young people showed somewhat more positive reactions than older respondents. For the time being, though, our results suggest that adjusting the color of the panels to the natural surroundings is a more promising route to increasing acceptance of alpine solar projects than more extravagant artistic elements.

5.1. Policy implications and recommendations for project developers

Our findings lead to several policy implications and practical recommendations. We show that from a social acceptance perspective, utility-scale solar PV projects in alpine regions could be a promising option of improving seasonal diversification of renewable electricity supply. Especially in situations where other options for increasing renewable energy supply in the winter season, such as wind energy or hydropower reservoirs, are facing social acceptance challenges, national policymakers might want to consider setting specific targets for solar power generation in alpine regions. They should also provide guidelines for project implementation to ensure that issues that are important for local acceptance, such as adequate benefit sharing schemes and securing low or even net-positive environmental impacts, are considered in the project development process. On a local level, including utility-scale solar PV projects in their spatial planning procedures and identifying suitable areas might be a way for alpine communities to attract new investment and allow for local value creation.

One useful instrument which stakeholders could refer to in the early stages of project planning would be a clear national- and local-level framework. In relation to this, and in line with our findings, project developers:

- are advised to design ownership models that contain a significant local component, possibly including options for citizens as potential to co-invest in the PV project. Such co-ownership models would allow local residents to participate in the financial value added of alpine solar projects.
- should be aware of the need to design projects in a way that is as closely adapted to natural surroundings as possible (e.g. using green solar panels and minimizing ecological impact).
- are well advised to keep in mind that fair processes are a precondition for maintaining the license to operate even if procedural justice was less of a concern for respondents in our sample. While residents will differ in the extent to which they want to be actively involved, and we found evidence that older citizens seek more involvement than younger ones, offering participation options for citizens during

the project planning phase may contribute to a smooth implementation process later on.

6. Conclusions

Through a targeted investigation of the attributes that determine the social acceptance of solar PV projects in alpine areas of Switzerland, this paper notably adds to the research stream concerning the social acceptance of solar PV. Specifically, two research questions were addressed: (1) *What are the attributes that determine the social acceptance of utility-scale solar PV projects in alpine regions,* and (2) *Which attribute levels can increase the local acceptance of a solar PV project?*

Based on a large-scale survey in Switzerland (N = 1036), we find that solar PV projects in alpine regions are associated with a high level of overall acceptance. 64% of all respondents indicated they would agree or fully agree with such a project, while only 14% of all respondents indicated they disagree or fully disagree. This suggests that among the options to provide seasonal diversification in renewable energy systems, alpine solar power generation looks like a potentially promising candidate from a social acceptance point of view. We also find more of a PIMBY than a NIMBY effect: the social acceptance level for residents of alpine regions is significantly higher (77% agree or fully agree with such projects; only 8% disagree) than among “lowlanders” residing outside those regions.

The results of the choice experiment confirm the findings of previous literature, especially within the literature for social acceptance of wind energy, suggesting that procedural and distributional justice, even though they are not the most important attributes in our choice experiment, correspond to higher levels of social acceptance. We also find that low environmental impact, as well as local ownership, are positively related to acceptance – this has already been identified for wind energy projects, with this research paper we demonstrate that it also applies to utility-scale solar PV projects in alpine regions. Importantly, we demonstrate that design can play a key role in either increasing or decreasing local acceptance of alpine solar projects. Participants clearly preferred a design which minimizes the visual impact of the project by adjusting the color of the panels to the natural surroundings: switching from conventional solar panels to green panels significantly increased the chances of the project being accepted. In contrast, the effect of innovative solar art features showed some variation among respondents, such as relatively higher support from young people, but did not have a positive effect on acceptance overall. To successfully implement solar PV projects in alpine regions, it appears to be crucial to keep them local and low-key, in the sense of minimizing the perceived landscape change.

6.1. Limitations and further research

There is still a lack of research about the social acceptance of utility-scale PV, in spite of the obvious relevance of solar power in the global energy transition. The choice experiment described herein adds important empirical insights to the related debate. Earlier research in this area has tended to focus on specific, isolated impacts (such as the impact of solar PV projects on tourism). We successfully deployed a choice experiment to quantify the relative importance of different attributes associated with a solar project based in an alpine region in explaining respondents’ level of acceptance of the latter. Moreover, we believe that the research is one of the first attempts to investigate the relative effect of a) design elements, as well as b) distributional and procedural justice on the level of social acceptance of solar PV. We also compare these effects with those of other attributes, including environmental impact and local ownership.

Naturally, the research involves limitations that suggest further research opportunities. First, our results are based on the chosen attributes and levels of a hypothetical alpine solar project. Further research could replicate our study with different attributes and different attribute levels. For instance, our study is the first to explore the influence of

innovative design elements on social acceptance of utility-scale solar PV. Our findings suggest, that innovative design elements decrease, rather than increase acceptance. Before taking this as an indication that design does not positively influence social acceptance, we would caution that this was probably the first time that respondents were confronted with the idea of such innovative design elements, and their preferences may change after they have had more time to get used to it. It would be interesting to see whether solar art finds higher support in regions where such projects have already been implemented, such as the panda-shaped PV projects in China, or whether participatory design processes, involving local schools or well-known artists, would lead to higher acceptance.

Second, our survey was conducted with a representative sample of the national population and controlled for differences between inhabitants of alpine regions and residents of other parts of the country. While average preferences of the population are an important determinant of social acceptance, further segmentation could lead to additional insights. For example, we observed significant differences between the preferences of young and old respondents with regard to design, but also to their preferred level of participation. Further research could investigate whether solar projects in alpine communities with a higher share of young people in the population or in local politics face less social acceptance challenges than projects in regions that are characterized by a different demographic setting.

Finally, our research project has focused on a particular geographical context. While Switzerland shares many similarities with other developed countries that have embarked on a low-carbon energy transition, there are also specificities such as a relatively high per-capita income, the absence of carbon-intensive domestic power generation, and a

tradition of participatory democratic decision making that might have influenced our findings. An examination of citizen preferences in different cultural contexts, such as alpine regions in Canada, Central Asia or South America, might also be fruitful.

Credit author statement

Pascal Vuichard: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization, Funding acquisition, Alexander Stauch: Methodology, Formal analysis, Writing – Review & Editing, Rolf Wüstenhagen: Conceptualization, Writing – Review & Editing, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Appendix A. – Survey introduction text

At the Institute for the Economy and Environment we are investigating various questions relating to the energy transition, including questions about solar energy. In order to gain important insights, we also conduct studies with end consumers. To participate in this study, you do not need to have any previous knowledge of solar energy. The present study is conducted for research purposes only.

We ask you to answer the questions truthfully. Our study is absolutely anonymous and no conclusions can be drawn about the participants. The data will not be passed on to third parties at any time.

We ask you to carefully read the following text on solar energy in general and on the solar project in an alpine region in particular. Afterwards you will be asked some questions:

In Switzerland, solar energy accounts for 3.4% of the Swiss electricity consumption. There is still great potential for the further expansion of solar energy. For this reason, the main goal is to use the huge areas on roofs and facades. However, one of the aims of the Energy Strategy 2050 is also to expand the production of renewable energy in the winter half-year. Ground-mounted solar PV projects in alpine regions can make a contribution to this. Due to their size, they are more economical than smaller roof systems. Alpine regions also benefit from increased solar radiation, fewer fog days, and additional snow reflection: optimal conditions for the production of renewable energy in the winter half-year.

Appendix B. – Hypothetical alpine solar PV project for Switzerland

Text

The solar project in the alpine region is expected to produce around 1.5 gigawatt h of electricity – equivalent to the annual electricity requirement of around 1250 people. The plant would have a total area of about 6000 m² (about the size of a football field) and be located on a slope in the vicinity of existing infrastructure (cable cars and buildings). The picture below shows you how such a solar PV project might look in reality (example illustration).

Illustration



Fig. s1. Illustration of hypothetical solar PV project in an alpine region (authors' figure, 2019).

Appendix C. – Conjoint attribute ‘Design of the solar PV project’



Fig. s2. Level 1: Conventional PV panels.



Fig. s3. Level 2: Green PV panels (adapted to surroundings).



Fig. s4. Level 3: Art element: animal design (Capricorn).



Fig. s5. Level 4: Art element: Swiss flag design.

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