Sierro and Blumer
Energy, Sustainability and Society (2024) 14:33
https://doi.org/10.1186/s13705-024-00465-0

Energy, Sustainability and Society

RESEARCH

Open Access

Material energy citizenship through participation in citizen-financed photovoltaic projects

Fabienne Sierro[1,2*] and Yann Blumer[1]

Abstract

Background Citizens are recognized as key actors in the energy system's transformation by assuming novel roles beyond being mere energy consumers. Participation in renewable energy projects increases societal support and renders the decarbonization of the energy system more inclusive. Increasing numbers of citizen-financed photovoltaic (CiFi PV) projects exemplify this. Empirical studies on individuals who participate in CiFi PV, their perceived role(s), and their motivations, however, are scarce. This study addresses this gap through the lens of energy citizenship by analyzing individual participation.

Methods The study surveyed CiFi PV participants across five projects in Switzerland ($N=510$). After a comparison of the participants' characteristics to the general public and a descriptive analysis of the perceived roles to participate, the study explores the individual motivations of participants. To that end, a motivational attributes scale, including finance, environment, local value creation, and symbolism, was adapted from a previous study. A hierarchical multiple linear regression was used to analyze which motivational attributes predict participants' willingness to participate in future CiFi PV projects.

Results While participants were primarily male, more affluent, better educated and politically more left-leaning than the average Swiss population, participants covered a wide range of sociodemographic characteristics and worldviews. Though CiFi PV is primarily marketed toward tenants, half of the participants were homeowners. Participants perceived themselves as energy citizens contributing to the energy transition and environmental preservation rather than as investors or energy producers. The regression analysis shows that motivations are relevant in explaining willingness to participate in future CiFi PV projects. We found that environmental, financial and local value creation-related motivational attributes are highly significant predictors, as well as slightly less significant symbolic attributes.

Conclusions These results suggest that CiFi PV projects represent a material form of energy citizenship going beyond mere consumerism by enabling individuals to contribute to the energy transition. Given their capacity to engage diverse publics, policymakers should endorse projects emphasizing individual participation alongside non-commercial community-based models. This would require their integration into existing regulatory frameworks. Future energy citizenship studies should further explore how individuals perceive and conceptualize what it means to be an energy citizen.

Keywords Citizen-financed photovoltaics, Energy citizenship, Material participation, Energy transition, Community energy, Switzerland

*Correspondence:
Fabienne Sierro
fabienne.sierro@zhaw.ch
Full list of author information is available at the end of the article

Background

Today's global energy system is unsustainable on social, economic, and environmental levels and in dire need of major transformation towards a more sustainable state [1]. Within this transformation process, citizens are becoming increasingly important [2, 3]. Financially, citizen-led initiatives have been estimated to account for investments of around 6.2–11.3 billion EUR supporting renewable energy development in 30 European countries from 2000 to 2021 [4]. Projects based on citizens' participation contribute largely to decentralized energy production, challenging traditional and centralized ownership structures of energy production and its benefits. This has contributed to academic interest in topics, such as energy democracy and energy justice [3, 5, 6]. Research has further suggested that such citizen-based projects positively impact the social acceptance of controversial renewable energy technologies [7–10].

Innovative ways to enable renewable energy projects have emerged, with citizens taking up new roles in providing alternatives to environmentally harmful fossil energy production. Both citizen-financed wind and photovoltaic projects are examples of that [10–12]. In this study, we focus on citizen-financed photovoltaic (CiFi PV) projects. These projects are based on citizens financing new solar power plants not located on the participating citizens' property [12]. In return for their investment, participants may receive their invested money back with interest or a certain share of the solar power produced by that project [12–14]. To offset the cost of coordination and management of many participants, typical CiFi PV projects include large (and thus cost-efficient) solar installations atop municipal or industrial buildings [15], as well as ground-mounted installations, e.g., in agricultural or mountainous areas.[1]

In academic literature, participation in CiFi PV projects and the underlying motivations have been conceptualized from two main perspectives: a social one (using the framing of community energy) and an economic one (framing them as a means to finance renewables). Both views employ a strong conceptual framing to the study of CiFi PV projects, which has led to a fragmented understanding of what drives citizen participation [16]. These studies have shown that financial [16, 17] and environmental [18] considerations are especially important for decision-making, but they provide contrasting evidence on the relative importance of either.

The CiFi PV market encompasses both grassroots- and market-oriented projects [15, 19]. Grassroots projects specifically arise from ideology-driven organizations, such as cooperatives or associations. While members of these organizations have voting rights and may be directly involved in financing the installation through loans and membership fees, they do not participate in the design or implementation of the specific solar power plant, nor do they necessarily form a community and have ownership rights. Market-oriented projects are not typically citizen-led or community-related but follow a more commercial and market-oriented logic [19]. CiFi PV projects are provided by various actors ranging from municipalities to traditional energy providers and private companies with differing levels of participative governance. Simultaneously, both grassroots- and market-oriented CiFi PV projects leverage various financing strategies, including crowdfunding, equity investments, lending, etc. [15, 19, 20].

To acknowledge the diversity of CiFi PV projects and study it as a new form of citizen involvement in the energy transition, we use energy citizenship as a lens to embed our research on CiFi PV participation motivations. In contrast to the concept of community energy, some authors argue that energy citizenship is not limited to any level of organization and may, for example, establish new energy practices at the private level [21, 22]. Even though scholars disagree on what defines energy citizenship [21], it might be useful for researching CiFi PV participation because of its broader understanding of energy projects rooted in citizen participation.

Various forms of energy citizenship have been and continue to be studied [22–25]. Within that body of the literature, citizen financing has received little attention up until now. Citizen-financed projects are worth considering, because they represent a common type of public participation in the European energy transition [26, 27]. Moreover, such projects have received attention at the European policy level. The European Union has defined two models that enable and promote energy communities, including projects based on citizen financing [28, 29]. However, this regulation only considers CiFi PV projects, which are conceptualized as an energy community. Projects which are not community-based are currently not regulated and promoted at the European policy level.

Citizen-financed projects have been found to improve social acceptance of renewable energy projects and thus bear the potential to expedite the energy transition [10, 12, 30]. Understanding what characterizes CiFi PV participants, what motivates them to participate in such initiatives and how they perceive their involvement may help us better understand what kinds of energy citizenships are practical and desirable in what setting. We

[1] An example of a ground-mounted CiFi PV project is "La Manganizza agrivoltaic plant", in Italy: https://renantis.com/media-centre/renantis-launches-third-agrivoltaic-project-in-italy-with-a-lending-crowdfunding-campaign/.

approach energy citizenship from a citizen perspective, exploring how CiFi PV participants perceive their role and participation and whether they associate it with energy citizenship.

Citizen-financed PV projects

CiFi PV projects represent a diverse phenomenon, which has been studied under various terms: "community energy participation" [8], "community financing projects" [31], "PV citizen participation initiatives" [16], "citizen solar power plants" [18], "bottom-up PV initiatives" [17], "crowdfunded renewable energy projects" [11] or "financial citizen participation" [20, 32]. The common denominator of these projects is that they are based on a group of individual citizens that jointly finance a renewable energy project outside of their own premises. In the case of CiFi PV projects, involved citizens finance the installation of new PV power plants. Hence, compared to prosumer models, CiFi PV projects tend to be larger in scope than a private house rooftop installation and are frequently installed atop commercial or public infrastructure. Furthermore, they mainly target tenants without the possibility of establishing a private PV installation on their premises [2, 15, 28].

Depending, however, on the national regulatory context and structure of the energy sector, CiFi PV models can vary considerably, e.g., in terms of their legal form (energy utility, commercial (start-up) company, cooperative, association, municipality, etc.), the role of its participants (merely financial investors or members with a voting stake), and—above all—business and payout models [20, 29]. These include the following four typical models [20, 32]:

Reward models give participants a non-monetary reward over a fixed period. Such models are often offered by energy utilities that grant their customers a reduction in their energy bill. This essentially corresponds to a long-term electricity contract at a fixed price. In *lending models,* participation comes as a loan with a fixed interest rate over a certain period. Non-commercial actors, such as cooperatives, associations, and municipalities, typically offer them. In *donation models,* the returns of a project are not given back to participants but are instead re-invested in additional projects or designated for other causes. Non-profit organizations almost exclusively provide such models. Eventually, *equity models* provide participants with a financial stake in the project, meaning that the return depends on the financial performance of that specific project (or a more extensive portfolio of projects). Commercial actors (start-ups, private ventures) usually provide such equity-based models.

Heterogeneous motivations with the potential to attract a large variety of citizens

Depending on the context and the studied population, studies emphasize various motivational factors influencing project participation. From a community energy perspective, factors such as social norms, trust, environmental concern [33], community identity [34], and long-term social concerns [35] were identified as determinants for the willingness to participate in renewable energy projects. In contrast, financial factors appeared to be less prominent. Studies adopting a stronger finance focus show that protecting the environment [18, 32] and a high level of active citizenship in associations [32] or financial motivations drive citizen participation [11, 16, 17]. Studies based on inferential statistics (logit regression analysis) find contradictory tendencies [16, 18]. While Braito and colleagues state: *"We do not suggest that economic incentives are dispensable or have negligible motivational power, but [...] we found that it is not just money that matters."* [18, p.150] and indicate that too strong financial incentives might even crowd out or inhibit individuals and households with stronger non-monetary motivations to participate in individual or collective PV projects, Fleiss et al. find that *"[...] economic drivers are identified as the major drivers behind adoption"* [16, p.925], emphasizing the contradiction of their results with a widespread narrative of CiFi PV projects serving mostly ideology-driven and pro-environmental citizens.

Koch and Christ [14] conducted a case study on a specific type of Swiss CiFi PV project provided by an electric utility. Based on a deductive and inductive qualitative approach, they identified the tangibility of such projects, the direct way to contribute to the energy transition, and the little effort and cost the participation represents as primary drivers of participation. Environmental motivations were found to be related to an understanding of the energy transition as an effort towards sustainability, while financial aspects were mainly associated with the price of the offer. Moreover, their study revealed interactions *"between the aspect of supporting sustainable power production, of supporting regional energy production, and – to a smaller extent – the assessment of the financial conditions."* [14, p. 423].

These varying findings highlight the heterogeneity of motivations underlying citizen participation in CiFi PV projects and the potential of such projects to attract various kinds of citizens.

Citizen-financed PV and material participation in the energy transition

In the current body of literature on energy citizenship, some scholars take a more normative view of the concept,

relating it exclusively to projects with strong advocacy for energy democracy and/or energy justice [22–25, 36, 37]. In contrast, others argue that energy citizenship can be material-based and linked to the adoption of objects and devices without directly impacting governance structures, such as using an electric car or a private PV installation [22, 37, 38]. Others contend that energy citizenship is not about what a citizen *"ought to become"* but rather about all kinds of relationships and interactions of citizens with energy and the energy systems [39, 40].

Within energy citizenship literature, photovoltaic panels have been linked to a materially based energy citizenship [22, 37]. Drawing from Science and Technology Studies, an interdisciplinary field investigating reciprocal relationships between science, technology, and society [41], and political science theory, Ryghaug et al. [22] utilize material participation theory to show how, for example, PV panels become *"objects of participation and engagement"* in matters of concern, such as climate change, sustainability, and the energy transition. Material participation represents a *"specific mode of engagement"* involving "*things, people, issues, settings, technologies, institutions and so on.*" [38, p. 2] and is "*an 'object-oriented' or 'device-centered' perspective that focuses on the role of technologies and material objects for (mundane) participation in political matters of concern.*" [22, p. 285].

The premise of understanding technologies, artifacts, and objects as vessels for participation opens a field of possibilities for citizens to engage in matters of personal concern. Today's centralized energy system provides just a few options for citizens to truly engage in the political economy. However, industries are increasingly relocating responsibility for sustainable consumption and behavior in the private sphere [37]. Most forms of participation are based on informational citizenship, which requires citizens to educate themselves on complex issues, often with little or no relevance to their everyday lives. Material participation, however, is action- and impact-oriented. Therefore, in-depth knowledge about complex issues, such as climate change, is not a prerequisite for taking action [38]. This echoes Devine–Wright's [42] precaution regarding whether the public is willing to take an enhanced, active role in complex matters requiring the acquisition of knowledge, learning, and taking responsibility. Material participation thus represents an interesting vessel for the broader population to engage in a complex and political issue, such as the energy transition.

As CiFi PV project developers often discursively promote their projects as a means to participate in the energy transition and to contribute to the expansion of renewables, these projects get explicitly linked to the political question of how the future energy system is to be envisioned, referring to public policies on the energy transition at large [15, 43]. As a result, we approach the study of CiFi PV participation with the premise that it might represent an opportunity for citizens to engage in the energy transition materially.

The outlined understanding of CiFi PV as a form of material participation implies the assumption that citizens participating in such projects aspire to motivations beyond mere consumerism. Rather, these motivations relate to the (desired) impact of CiFi PV projects. As shown by previous studies on CiFi PV participation, a large variety of motivations exist, hinting at citizen financing representing more than a simple financial transaction.

Research questions

Considering the current state of knowledge, this study aims to approach the phenomenon of CiFi PV, focusing on the individual participants instead of the community or community-specific aspects. For that, we embed this study in the concept of energy citizenship rather than employing an energy community perspective. We aim to provide empirical data on the characteristics of individual CiFi PV participants and their perceived role(s) in the energy transition. This forms the basis for exploring the influence of different motivational factors on the willingness to participate in future CiFi PV projects. Thereby, we examine whether citizen financing projects represent a form of continuous engagement within the energy transition and a material form of energy citizenship. We thus address the following research questions:

1) What characterizes CiFi PV participants in comparison with the general public?
2) How do CiFi PV participants perceive CiFi PV participation and their role(s) within such projects?
3) What motivations determine CiFi PV participants' willingness to participate in future CiFi PV projects?

We conducted a quantitative online survey among participants in five CiFi PV projects in Switzerland to gather empirical evidence. The Swiss CiFi PV market is growing and has a high degree of project diversity, making it an ideal case study [14, 15].

Methods

The core of this study forms a survey of a sample ($N=510$) of participants in five different CiFi PV projects in Switzerland, using exploratory questions regarding perception of participation and role, as well as an adapted motivational attributes scale developed by Noppers and colleagues [44, 45]. First, the sample was characterized and compared to the general population of Switzerland using data from the Swiss Household Energy Demand

Table 1 Overview of practice partners and recruited CiFi PV participants for this survey study, including corresponding dummy coding

Project developer	Population*	Response rate	Valid N	Payout model	Linguistic area	Area of activity	Dummy-coding
Private venture	700	172 (25%)	145 (21%)	Equity	German	Supra-regional	1
Utility 1	120	74 (62%)	57 (48%)	Reward	German	Local	2
Utility 2	495	246 (50%)	189 (38%)	Reward	French	Local	3
Municipality	50	64 (78%)	27 (54%)	Loan	French	Local	4
Cooperative	350	107 (31%)	92 (26%)	Loan	French	Local	5
Total	1715	633 (39%)	510 (30%)				

**Note: Estimate based on information from project developers with varying degrees of accuracy*

Survey (SHEDS) [46]. Second, we applied a descriptive analysis of the exploratory items regarding participants' engagement and role perception. Third, we employed a two-step multiple linear regression to understand which motivations predict participants' willingness to participate in future CiFi PV projects. As previous studies using logistic regression analysis [16, 18] have led to diverging conclusions regarding the importance of environmental or financial motivations, we opt for a different methodological approach to further understand to what extent motivations are explanatory for willingness to participate in such projects. The two-step multiple regression analysis allows us to provide a more detailed picture of the explanatory strength of our construct of interest (motivations) compared to control variables [47]. The following subchapters give an overview of the empirical context (Empirical context: Citizen-financed PV in Switzerland), sample and survey structure (Sampling and survey structure), and the employed measures (see Measurement model and subchapters).

Empirical context: Citizen-financed PV in Switzerland

Apart from a sizeable number of energy cooperatives, which have a long tradition in Switzerland [31, 48, 49], Swiss residents have access to a growing number of almost 50 different CiFi PV offers [15]. The diversity of CiFi PV projects has various reasons. One factor is the absence of a regulatory framework to define and support community energy models in Switzerland, in contrast to the European Union, where such frameworks are established [28, 29]. In addition, there are pronounced regional variations in subsidies and feed-in tariffs for solar power [50, 51]. Another contributing factor is the current lack of possibilities for Swiss households to choose their energy providers, resulting in several hundred local utilities across the country [52]. These utilities, motivated by exploring new business opportunities or responding to political pressure, have been key drivers behind the growth of CiFi PV offers in recent years [15]. Consequently, many CiFi PV projects are constrained to a specific subset of the population, typically the customers of a particular municipal utility [14, 15].

While some of this context may differ from the situation in other countries, Switzerland provides a suitable case to study CiFi PV. On the one hand, there is considerable market potential due to the large share of residents living in rented apartments (almost 60%, according to the European Commission 2023 [53]) and their affluence compared to neighboring countries. On the other hand, the divide between grassroots and market-based actors may be less pronounced than in other countries, owing to the country's direct democracy that grants citizens the power to veto energy policies and projects. The fact that municipalities own most electricity utilities adds to the democratic control of the energy system. Consequently, CiFi PV in Switzerland can be conceptualized as one phenomenon, even though individual projects may differ in payout models or project developers.

Sampling and survey structure

We recruited participants via five project developers to obtain a large sample of Swiss residents who already invested in CiFi PV. These reflect the diversity of the Swiss CiFi PV market in terms of payout models, type of provider, and location (see Table 1). A link to an online survey was sent to everyone who has invested in one of their projects through internal mailing by these five providers. The data collected did not include any additional information (e.g., personal information, customer number, etc.) and was not provided by the participants.

The survey was conducted between November 2021 and January 2022 in the respective language of the project developers. After one week, reminders were sent out. Furthermore, participation was incentivized through a lottery offering prices with a total value of 1000 Swiss Francs (about 1000 EUR) to five randomly drawn winners. After removing fraudulent, duplicate,

or incomplete surveys from 633 replies, $N = 510$ valid responses remained.

The survey consisted of three parts. First, respondents were asked for information concerning their investment(s) in CiFi PV projects (number and volume of investment(s), date(s) of investment(s), and overall satisfaction with their investment(s)). Second, the survey focused on CiFi PV in general, without reference to any particular projects. Respondents were asked about their willingness to participate in future CiFi PV projects and to indicate motivational attributes, as well as their perception of their role when investing in such projects. Third, respondents were asked sociodemographic questions such as income, housing situation, gender, age, education, and political orientation, as well as questions regarding principles of life and level of civic engagement.

To answer our first research question regarding the characteristics of CiFi PV participants in comparison with the general public, the questions used in the last part were informed by the Swiss Household Energy Demand Survey, an annual survey aiming to describe a household's energy-related behaviors and changes [46]. This allowed for comparing the samples' characteristics with the general Swiss population, using SHEDS data from 2018 and 2021. All questions were mandatory. Participants were given the option 'no answer' for sensitive questions such as political orientation or income.

Our second research question focuses on the perception of participation and the role of actual CiFi PV participants. We created two multiple-response questions asking respondents how they perceive their participation in CiFi PV and which role they attribute to themselves and analyzed the results descriptively. As no adequate measurement instrument exists in the literature, questions and responses were formulated on an exploratory basis inspired by results from previous qualitative research on Swiss CiFi PV [14, 15] and the concept of energy citizenship [20]. Respondents could, for example, select different roles they associate with in their CiFi PV participation, such as energy citizen, environmentalist, and/or investor.

Measurement model

To address our third research question concerning what motivations may influence participants' willingness to participate in future CiFi PV projects, we first adapted an existing scale on motivational attributes [44, 45] and conducted a principal component analysis. We then built a two-step multiple regression model testing the introduction of our motivational attribute components and control variables.

Principal component analysis for measuring motivational attributes of citizen-financed PV projects

We adapted the Noppers and colleagues [44, 45] scale to measure instrumental, symbolic, and environmental motivations for adopting sustainable innovations, such as smart energy systems and electric vehicles. We chose this scale as it measures (desired) impact through the participation in or the adoption of a specific sustainable innovation. This aligns with our conceptualization of CiFi PV projects as a potential form of material participation. We modified and adapted the scale to CiFi PV projects and used a 5-point Likert scale ranging from '1—Completely disagree to 5—Completely agree' (see Table 2 for the adapted scale).

Environmental and symbolic attributes were adapted to the CiFi PV context. Part of what Noppers and colleagues measure with instrumental attributes is related to financial motivations. Previous studies on CiFi PV participation identified monetary gain through attractive interest rates and control over the money flow, providing investment security as drivers for participation [11, 16]. As previous research has provided contrasting evidence on whether CiFi PV participation is mainly determined by financial or environmental motivations, we decided to operationalize instrumental attributes by financial aspects. Hence, we further refer to these items as financial attributes. With that modification, we aimed at a clear distinction between environmental- and finance-related motivational attributes.

We added a motivational category called 'local value creation'. With this category, we aimed to grasp motivations identified in previous research that did not fit into the existing scale categories. Particularly for the Swiss context, Koch and Christ's [14] qualitative study identified the tangibility and transparency of local CiFi projects (including local actors) and that they provide local electricity as the main drivers for participation. They summarized these aspects as a separate motivational category that they named "regional factor" and showed that interactions between financial, environmental, and regional motivational factors exist. A set of interviews from a research project on Swiss CiFi PV projects supports these findings [15]. Hence, we created the category 'local value creation' to capture (desired) tangible impact within the scope of CiFi PV participants' local realities. The specific added items were: 'Support for local actors'; 'Contribution to the sustainable development of the region'; 'Financing of implementation of a tangible project'; and 'Having an impact together with others.' It is to be noted that the term 'local' does not relate to a specific physical area but rather to a space of personal importance to every participating citizen.

Table 2 Component loadings based on a principal component analysis of the motivational attributes scale (loadings below 0.3 suppressed)

Item	M / SD	Communalities	Component loadings			
			Environment	Finance	Local value creation	Symbolism
Protecting the environment	4.0 / 0.94	0.80	0.86			
Fighting climate change	4.1 / 0.95	0.89	0.92			
Reducing CO^2 emissions	4.2 / 0.84	0.78	0.85			
Controlling where my money flows	3.4 / 1.33	0.57		0.64		0.34
Making a financial gain	2.5 / 1.16	0.79		0.87		
Investing my money safely	2.9 / 1.23	0.76		0.85		
Financing the implementation of a tangible project	4.6 / 0.75	0.62			0.76	
Having an impact together with others	4.3 / 0.86	0.62			0.76	
Supporting local actors	4.3 / 0.90	0.71			0.83	
Contributing to the sustainable development of my region	4.4 / 0.85	0.53	0.38		0.60	
Differentiating myself from others	2.6 / 1.29	0.74				0.84
Showing who I am	2.3 / 1.30	0.78				0.86
Saying something positive about myself	2.8 / 1.36	0.74				0.84

Note: $N = 510$; extraction method: principal component; varimax rotation; 4 components extracted, explained variance = 72%; Kaiser–Meyer Olkin = 0.80; Bartlett test of sphericity: $p < 0.001$, Cronbach's $\alpha = 0.82$

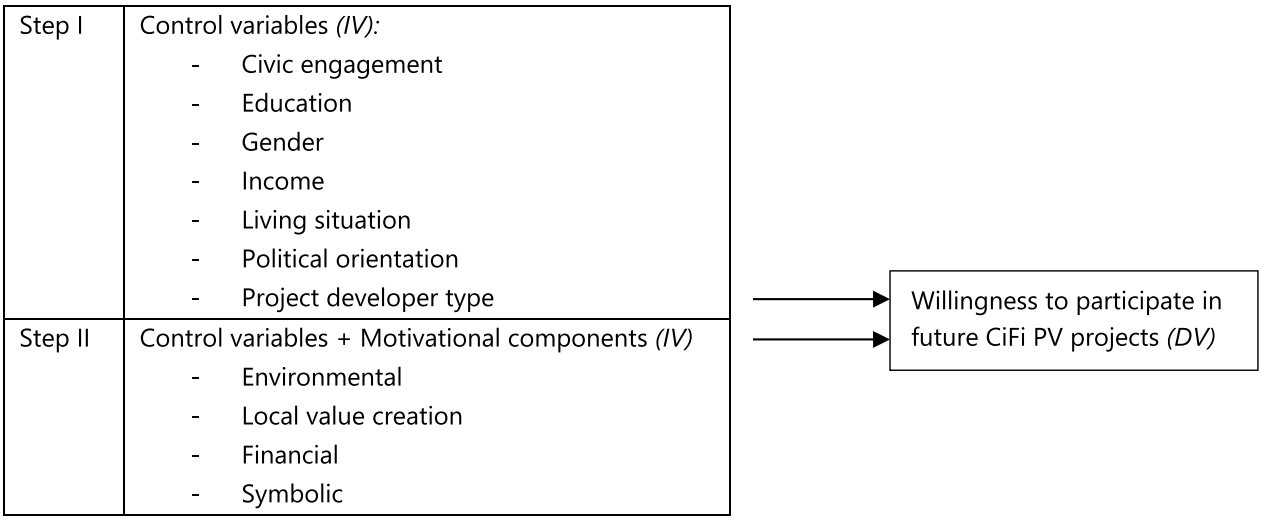

Fig. 1 Conceptual model for the two-step multiple linear regression model (own illustration)

Table 2 shows the validation of the adaptation and extension of Nopper's motivational attributes scale to CiFi PV using a principal component analysis (PCA). The analysis yields a four-dimensional solution corresponding to the theoretically established dimensions of finance, environment, local value creation, and symbolism. The Kaiser Meyer Olkin value of 0.80 indicates a good fit of our data for PCA, and the significant result of the Bartlett test of sphericity ($p < 0.01$) points to correlations between the variables [54, 55]. Two items show cross-loadings with loadings below 0.4, which can be considered negligible [55]. For further analysis, we used each component's loadings (coefficients).

Two-step multiple linear regression model

Figure 1 depicts the conceptual model for the two-step multiple linear regression model. To measure whether CiFi PV participants are potentially willing to engage in such projects on a long-term and repeated basis, we measured their willingness to participate in future

projects [56]. We asked participants to rate their willingness to participate on a scale from '1 – Very low' to '5 – Very high'. Participants were highly willing to participate in future CiFi PV projects, with 70% of respondents choosing high and very high as their answers (M = 4.03, SD = 1.086). This variable was used as the dependent variable (DV) in our regression model.

Independent variables (IV) consisted of control variables, entered at stage I, and the motivational components derived from the PCA analysis, entered at stage II. This hierarchical procedure provides a more detailed picture of the variables explaining willingness to re-participate. It allows us to estimate the additional explanatory power of a construct of interest compared to control variables [47]. Checking for theoretical assumptions of multiple linear regression analysis, we found no indication of heteroscedasticity or multi-collinearity nor serious violations of the assumption of normal distribution.

For step I, we included standard sociodemographic characteristics, such as gender, age, income, education, as well as civic engagement, housing situation, political orientation, and project developer. Previous research [31] has identified educated, affluent, older men as CiFi PV projects' target groups. We added the level of civic engagement and housing situation (tenant, owner, member of a housing cooperative) as control variables because of recent studies showing that CiFi PV participants are highly civically engaged in associations or clubs [32], and CiFi PV projects frequently target tenants [2, 15, 28]. As a proxy for the linguistic region, we tested for differences between the five project developers who gave us access to their members/clients. For that, we dummy-coded project developers from 1 to 5 and used the project developer with the largest number of participants as a reference category (see Table 1 at the beginning of the method section) [55].

For step II, we introduced our motivational attribute coefficients as yielded in the four-dimensional PCA conducted beforehand. We thus used the four components of environmental, financial, local value creation, and symbolic motivational attributes and measured their influence on participants' willingness to participate in future CiFi PV projects. To assess whether the varying group sizes of the sample impact the regression model, we conducted Chi-square and ANOVA tests across our independent regression variables by project developer type. The analysis shows that none of the motivational attribute categories varies significantly across the five groups. Of the control variables, civic engagement, education and tenancy showed significant results, but no pattern with regards to any specific group biasing the regression results could be identified.

Results

Sample characterization in comparison with the Swiss general public

Our first research question regards the characteristics of CiFi PV participants compared to the general public. Table 3 provides an overview of the characteristics of our sample and the Swiss population based on data retrieved from SHEDS 2018 and 2021. The sample consists primarily of male participants (75%). There are slightly more homeowners (50.6%) than tenants (43.5%). Respondents exhibit an extraordinarily high level of education, with almost 80% having obtained a degree of higher education (technical college, university, PhD), compared to 63% in SHEDS. Consistent with the high educational level, over half of the sample have a monthly household income above 9,000 CHF[2] (37% in SHEDS), while just 7.6% earn less than 4,500 CHF[3] (13.5% in SHEDS).

Our sample is politically slightly more left-leaning than the SHEDS sample. However, participants' political orientations span the entire political spectrum. They also display higher levels of civic engagement, with around 60% being active members of clubs or associations compared to 46% in SHEDS. They are mainly engaged in environmental, political, and neighborhood associations. Concerning principles of life, the sample is fairly similar to the Swiss population, except that the sample appears to be slightly more guided by biospheric life principles and less by hedonic values.

Participants see themselves as environmentally responsible energy citizens

Our second research question focuses on how CiFi PV participants understand their engagement and role within such projects. Table 4 provides an overview of how respondents perceive their participation. 86% of the respondents indicated that they see their participation as a contribution to the energy transition, and 82% see it as an environmental commitment. Other options, conceptualizing CiFi PV participation as a financial investment, a donation for a pioneer project, or a political commitment, were selected by about one-third, and only a clear minority considered their participation support of small- and medium-sized enterprises (SME)/startups or a personal learning opportunity.

Table 5 shows participants' perceptions of their individual roles. 58% of the respondents identified as energy citizens, 48% as environmentalists, and around a third as energy producers, investors, or clients.

[2] Approximately 9100 Euros in 2023.

[3] Approximately 4550 Euros in 2023.

Table 3 Characteristics of CiFi PV participants and the Swiss population (nominal and interval variables)

Variable	Coding	Distribution	
		CiFi PV participants	Swiss population
Active membership in a club or association *(N = 510)*[1],[2]	1 = No meetups or very rarely (low)	39.8%	53.7%
	2 = ≤ 1 monthly meet-up (medium)	33.3%	22.0%
	3 = ≥ 1 weekly meet-up (high)	26.9%	24.3%
Type of engagement of the civically engaged respondents *(N = 365)*[1],[3]	1 = Sports club	27.8%	32.8%
	2 = Other	20.4%	25.6%
	3 = Environmental organization	15.7%	5.1%
	4 = Political organization	11.7%	7.3%
	5 = Neighborhood association	9.8%	5.7%
	6 = Music club	7.3%	10.2%
	7 = Union	3.1%	4.3%
	8 = Service club	2.3%	3.1%
	9 = Student organization	0.9%	3.5%
	10 = Parents' association or youth club	0.9%	2.4%
Gender *(N = 510)*	0 = female	23.3%	51.0%
	1 = male	76.7%	49.0%
Education *(N = 510)*	1 = Compulsory school (low)	0.8%	2.7%
	2 = Vocational training, high school (medium)	18.2%	34.1%
	3 = Technical college, university, PhDs (high)	79.2%	63.1%
Income (monthly) *(N = 510)*	1 = < 4500 CHF (low)	7.6%	13.5%
	2 = 4500–8999 CHF (medium)	33.7%	35.6%
	3 = ≥ 9000 CHF (high)	50.2%	36.7%
	No answer	8.4%	14.2%
Homeownership *(N = 510)*	1 = Owner	50.6%	36.4%
	2 = Tenant	43.5%	60.6%
	3 = Member of cooperative	5.7%	3.0%
Political orientation *(N = 510)*	1 = Left	9.6%	5.1%
	2	20.2%	11.6%
	3	20.8%	20.2%
	4	19.0%	23.0%
	5	17.5%	19.5%
	6	9.2%	13.0%
	7	2.0%	5.4%
	8 = Right	0.6%	2.2%
	No answer	1.2%	–
Age *(N = 506)*	Continuous scale with an open text field	Mdn = 54	Md*n* = 43[4]
Principles of life Altruistic (A) Egoistic (E) Biospheric (B) Hedonic (H) *(N = 510)*	Likert scale from '1 Not important at all—5 Very important'	A: M = 4.1, SD = 0.61 E: M = 2.5, SD = 0.71 B: M = 4.4, SD = 0.57 H: M = 3.5, SD = 0.78	A: M = 4.0, SD = 0.94 E: M = 2.6, SD = 1.04 B: M = 4.0, SD = 0.88 H: M = 3.9, SD = 0.91

[1] The data provided are based on results from SHEDS 2018 with N = 5011, as the item was not included in the SHEDS questionnaire of 2021; [2]46% of the respondents from the SHEDS survey 2021 gave no answer to this question. The percentages presented in the paper were thus calculated with an N = 2706; [3]145 CiFi PV participants indicated being no member of any club or association. [4]Data retrieved from the Swiss Federal Statistical Office on the median age of the Swiss population in 2021 [57]

Motivational attributes influence willingness to participate in future projects

To answer our third research question regarding motivations determining willingness to participate in future CiFi PV projects, we conducted a two-step multiple linear regression. Both models are significant (see Table 6). As revealed by the hierarchical introduction of the control variables and the construct of interest,

Table 4 Multiple-response answers (in %) on the perception of the personal CiFi PV participation—"How do you perceive your participation? My participation is… " ($N=510$)

Perception of individual CiFi PV project participation	N	%
Contribution to the energy transition	438	85.9%
Environmental commitment	419	82.2%
Donation for a pioneer project	196	38.4%
Financial investment	193	37.8%
Political commitment	143	28.0%
Support for SME/startups	57	11.2%
Personal education	15	2.9%
Other	14	2.7%

Table 5 Multiple-response answers (in %) on the perception of the individual role in the CiFi PV project—"Within the scope of my participation, I see myself as…" ($N=510$)

Perception of individual role in CiFi PV project	N	%
Energy citizen	294	57.6%
Environmentalist	243	47.6%
Energy producer	179	35.1%
Investor	162	31.8%
Client	145	28.4%
Other	18	3.5%

motivational attributes increase the overall explained variance from 8.7% (adjusted $R^2=0.087$) of model 1 to 19.8% (adjusted $R^2=0.198$ of model 2. We thus observe an increase in explanatory power between the two models of 11.1%. Due to the high complexity of modeling human behavior, a model with R^2 values between 0.1 and 0.5 is considered "good" in social science, at the condition that most or all the explanatory variables are significant [58]. The obtained results thus indicate that motivations influence citizens' willingness to participate in CiFi PV beyond control variables. However, motivations alone do not appear to provide a comprehensive explanation.

Of all four significant motivational attributes, local value creation attributes ($B=0.227$, $p<0.001$), followed by financial attributes ($B=0.210$, $p<0.001$), and environmental attributes ($B=0.172$, $p<0.001$) are the strongest predictors. Symbolic attributes are less significant ($B=0.117$, $p=0.015$). This indicates that attributes related to the tangibility and local impact of CiFi PV projects especially motivate a higher willingness to participate in future projects. We find that local value creation factors are an additional explanatory factor to financial and environmental attributes.

Amongst the control variables, we find a negative, significant relationship between project developer 1 and willingness to re-participate ($B=-0.564$, $p<0.001$), indicating that participants related to this specific project developer are less willing to participate in future CiFi PV projects in comparison with the participants from other project developers. Between income and willingness to re-participate, we find a positive, significant relationship ($B=0.171$, $p=0.031$), meaning that the higher the participant's income, the more willing the person is to re-participate. Being a member of a housing cooperative has a negative, significant relationship with willingness to re-participate ($B=-0.643$, $p=0.005$), indicating that tenants and homeowners are more willing to participate in future projects. Interestingly, no significant relationship could be observed for both tenants and homeowners as reference categories. Therefore, the willingness to (re-) participate does not seem to depend on whether a participant is a tenant or a homeowner. Political orientation is negatively and significantly related, indicating that adopters who lean left politically are more inclined to participate in future CiFi PV projects ($B=-0.066$, $p=0.031$). Concerning civic engagement, age, education, offer orientation, and gender, we do not find any significant relationships with the dependent variable.

Discussion

We first discuss the characteristics of our sample and its implications for the expansion of CiFi PV projects. Second, we focus on motivations underlying CiFi PV participation. Finally, we discuss the perception of participants' roles and engagement and the implications of our findings concerning material participation and energy citizenship. We end by outlining the limitations of this study and possible avenues for further research in the field.

Citizen-financed PV projects: potentially attractive for large parts of the population

This study focuses on citizens who have converted their interest in CiFi PV projects into action. While our sample differs from the average population, it does not appear to form a coherent and narrow group regarding their sociodemographic characteristics and worldviews. Contrary to the widespread narrative that CiFi PV projects are mainly aimed at tenants [2, 15, 28], this study shows that homeowners make up a similar share of CiFi PV participants. Compared to the Swiss average population, homeowners are, in fact, slightly overrepresented in our sample. One explanation may be that homeowners tend to be more affluent than tenants. Moreover, there are several reasons why homeowners may be unable to realize a project on their own roof, e.g., because of an unsuitable roof (small solar potential, insufficient load-bearing

Table 6 Influence of different variables on the willingness to participate in future CiFi PV projects (results of a hierarchical multiple linear regression)

	Step I				Step II			
Variables	**B**	**SE**	**β**	***p* values**	**B**	**SE**	**β**	***p* values**
Constant	4.114	0.519		< 0.001***	4.115	0.488		< 0.001***
Age	− 0.010	0.004	− 0.133	0.011*	− 0.007	0.004	− 0.100	0.054
Civic Engagement[a]	0.044	0.060	0.033	0.467	0.029	0.056	0.022	0.604
Education[b]	0.113	0.124	0.044	0.366	0.059	0.117	0.023	0.615
Male[c]	0.081	0.122	0.031	0.508	0.103	0.117	0.040	0.379
Income[b]	0.163	0.084	0.098	0.053	0.171	0.079	0.102	0.031*
Tenant	0.117	0.116	0.055	0.314	0.046	0.109	0.022	0.673
Housing cooperative	− 0.638	0.243	− 0.123	0.009**	− 0.643	0.229	− 0.124	0.005**
Political orientation	− 0.079	0.032	− 0.117	0.015*	− 0.066	0.031	− 0.098	0.031*
Project developer1[d]	− 0.521	0.127	− 0.220	< 0.001***	− 0.564	0.122	− 0.238	< 0.001***
Project developer2[d]	− 0.278	0.167	− 0.084	0.097	− 0.150	0.160	− 0.045	0.347
Project developer4[d]	− 0.144	0.217	− 0.032	0.508	− 0.196	0.210	− 0.043	0.352
Project developer5[d]	0.048	0.148	0.017	0.749	− 0.007	0.140	− 0.003	0.957
Environmental attributes					0.172	0.047	0.159	< 0.001***
Financial attributes					0.210	0.051	0.195	< 0.001***
Local value creation attributes					0.227	0.045	0.216	< 0.001***
Symbolic attributes					0.117	0.048	0.109	0.015*
Model statistics	**Model 1**				**Model 2**			
R^2	0.111***				0.226***			
Adjusted R^2	0.087***				0.198***			
R^2 change	0.075				0.113			
Fchange (df1, df2)	4.6 (12, 440)				16.13 (4, 436)			
	N = 453				*N* = 453			

Note: B = unstandardized regression coefficient, SE = standard error; β = standardized regression coefficient; *p < 0.05; **p < 0.01; ***p < 0.001; [a] Coding: 1 = Never, 2 = Sometimes, 3 = Frequently; [b] Coding: 1 = Low, 2 = Medium, 3 = High; [c] Coding: 0 = female, 1 = male; [d] Dummy Coding: 0 = Other project developers, 1 = Project developer 1,2,4 or 5 (Reference category: Project developer 3); The political orientation scale is a continuous variable with higher values corresponding to stronger right-wing orientation (1 = left; 8 = right); Dependent variable: Willingness to participate in future CiFi PV projects

capacity, planned renovation) or complicated ownership situations (condominium with many owners that need to agree). This indicates the potential of CiFi PV projects to attract homeowners as an additional target group to tenants, thereby increasing the projects' reach to the public.

However, certain differences between our sample and the Swiss average population require some attention. Swiss CiFi PV participants are primarily male, well-educated, and affluent. This confirms findings from previous studies focusing on Switzerland and Germany [31, 32, 35]. This gender bias may be due to several reasons, including traditional gender roles at the household level and women generally earning and saving less [59], as well as having less affinity to (renewable energy) technologies, such as smart meters [60], electric vehicles [61] or e-bikes [62]. Further research is needed to discover if and how gender might affect citizen-funding projects and whether gender-related biases could represent a barrier and make citizen-funded projects less accessible to women than to men. The difference in affluence between participants and the general population suggests that even though participating in a CiFi PV project may represent a smaller barrier than, for example, a private PV installation, it nonetheless requires a stable financial situation [14, 31]. As previous research shows [31], Swiss citizens tend to see cost as much less of a barrier to participating in renewable energy crowdfunding, while Austrian citizens see this as the top barrier. Still, this study shows that a higher income positively influences willingness to participate in future projects. This suggests that an individual's financial means may play a role in the decision to participate in CiFi PV projects.

Not just money and environment: local value creation through citizen-financed PV project participation

Drawing on Noppers et al.'s [44, 45] conceptual model on motivations to adopt sustainable innovations, we developed and tested an extended motivational attributes scale for CiFi PV. This study confirms that there is indeed a wide range of motivations underlying CiFi PV

participation. They include financial, environmental, local value creation, and—to a lesser extent—symbolic motivations. We find that local value creation is put forward as a motivational driver that is distinct from financial and environmental aspects. This provides a possible explanation of why previous studies have come to different findings on the role of environmental [18] or financial motivations [16, 17] as drivers of participation and would have to be further tested with samples of the general population instead of CiFi PV participants. Moreover, our results show that of the five project developers, the one providing equity-based and nationwide projects significantly influences willingness to participate in future projects. While it appears that linguistic region has no effect, this may indicate that certain project characteristics, such as, e.g., payout model and geographical range of activity, require further investigation in relation to willingness to participate.

Our findings suggest that local value creation might be an understudied motivation compared to its potential explanatory relevance, as financial and environmental factors do not appear to fully capture the range of underlying motivations. Such local value creation motivations are mostly based on the tangibility of CiFi PV projects. Photovoltaics is a well-known and widely used technology, making a CiFi PV project and its impact practical and understandable. Simultaneously, PV panels render renewable electricity visible, altering the local reality of energy generation [22, 63]. As Koch and Christ [14] found in their study of a specific Swiss CiFi PV project, the 'local' aspects of CiFi PV projects embody the idea of reducing the complexity of a matter like the energy transition and rendering it actionable rather than a specific physical space.

Citizen-financed PV projects as an opportunity for material energy citizenship

Our findings further show that CiFi PV participants identify as energy citizens and environmentalists rather than investors. Being an energy citizen and environmentalist appears to be specifically associated with contributing to the energy transition and making an environmental commitment. This study thus provides evidence that CiFi PV participants associate their participation with two public and political issues: the energy transition and the protection of the environment.

This conforms to the notion of energy citizenship as a citizen-energy-system interaction [39, 40]. Furthermore, it appears to be consistent with the concept of material participation, defined as an engagement with a public and political problem through an object or a device [22, 37, 38]. Having conceptualized material participation as a form of energy citizenship, Ryghaug et al. have argued that material energy citizenship has a strong potential to contribute to energy transitions and strengthen citizens' identification as energy citizens [22]. The findings of this study suggest that CiFi PV projects represent an opportunity for citizens to act as materially engaged energy citizens, thereby providing evidence that is in line with the reasoning of Ryghaug and colleagues. However, economically less-privileged citizens might be unable to access citizen-funded energy projects and, therefore, be excluded from this form of participation [21, 22, 25].

Limitations and further research

While the study at hand provides a unique insight into the motivations and characteristics of participants in different CiFi PV projects, it does have several limitations that need to be considered when interpreting the findings and which may provide opportunities for future research.

First, despite the inclusion of participants in five different CiFi PV projects and a solid overall response rate, the sample size is not large enough for a detailed comparison between different groups of CiFi PV participants. In the Swiss context, for example, comparing the motivations of participants of CiFi PV projects offered by utilities and other actors might yield insights into how policies can design and support such offers to reach specific target groups. Similarly, conducting the study across different countries would allow for a better understanding of the motivations of CiFi PV participants in different national contexts (energy discourses, energy sector structure, affluence, etc.).

Second, due to the cross-sectional design, there was an unequal time (from a few weeks up to several years) between study participants' decision to participate in a CiFi PV project and them filling out the survey. This can introduce bias, such as unequal salience of participation experience. One way to mitigate this would be to collect data continuously by surveying participants shortly after signing up for a specific project.

Third, the survey focused on questions regarding CiFi PV in general. However, participants' experience with specific projects may have influenced their answers. This bias is inherent to the study of actual CiFi PV participants but, in turn, allows for more realistic data than what can be obtained with, e.g., an online experiment.

Fourth, data collection may have been subject to several biases. For one, there may have been self-selection bias, especially in the case of project developer groups with a low response rate. Next, participants' motivations were measured rather directly, which carries the risk of getting answers that suffer from social desirability bias (e.g., participants who were motivated by financial considerations may want to emphasize non-financial ones). To address this, indirect questioning methods might be tested, e.g.,

by asking participants to predict motivations for an average Swiss citizen rather than themselves [64]. Lastly, the survey did not provide participants with definitions of possible roles (such as 'energy citizen'). Hence, we cannot control for differences in understanding of these (rather abstract) concepts. The rationale for this was to explore how these terms, which have quite a distinctive meaning in academic discourse, resonate with citizens. Additional qualitative interview studies may provide a better understanding of individuals' underlying understanding of such terms.

Fifth, this study developed and tested an extended motivational attributes scale measuring motivations underlying CiFi PV participation. Future studies should pay particular attention to the meanings attached to local dimensions. While the scale presented in this paper is a valuable tool to measure a wide range of motivations, it can be further improved. For example, the item 'Contributing to the sustainable development of my region' loaded both on the components 'local value creation' and 'environmental' attributes. However, it loaded more strongly on the first one. By excluding the word 'sustainable,' it is plausible to think that the item measures the aspect of local value creation more accurately and has less of a link to environmental considerations.

Finally, the hierarchical linear regression approach suits the purpose of understanding to what extent a theoretical construct may increase the explanatory power of a model in comparison with control variables. With our two-step procedure, we were able to show that motivations increase the explanatory power of our model significantly. However, we find that predicting participation willingness is a complex matter and would require the inclusion of further theoretical constructs regarding human behavior. To extend and deepen the analysis, a complex theoretical model would be necessary, requiring more advanced models such as, e.g., structural equation or multilevel modeling.

Conclusion

This study contributes to the debate around motivations underlying CiFi PV participation, informing project developers about potential marketing strategies and target groups, and provides a first conceptualization of CiFi PV participation as a form of material energy citizenship.

We found local value creation motivations, referring to a mental image of a space considered relevant and actionable by an individual citizen, to be an important participation driver. CiFi PV participants identified mainly as energy citizens and environmentalists who contribute to the energy transition and commit to the environment. Despite CiFi PV participants appearing to be male, highly educated, and affluent, this study shows that the expansion potential of these projects is potentially high because actual CiFi PV participants do not form a narrow subgroup of the Swiss population. CiFi PV projects attract not just tenants but also homeowners, indicating that such projects may be more inclusive than often assumed. With a high willingness to continue engaging in CiFi PV projects, participants remain a target group with the potential to disseminate such projects further.

The fact that actual CiFi PV participants understand their participation as a contribution to the energy transition and are motivated by related environmental and local value creating aspects, suggests that these projects represent an opportunity for citizens to engage materially and meaningfully with the energy system. In addition to existing regulatory frameworks about energy community initiatives, commercial CiFi PV projects should be integrated and promoted to seize this opportunity. Furthermore, attractive feed-in tariffs, simplified sell-off procedures, and integration of CiFi PV investments in tax deduction schemes, similar to existing regulations concerning private PV installations, may enhance their attractivity to the general public.

For practice, these results indicate that a marketing strategy focusing on the tangibility and the local aspects of such projects may foster CiFi PV participation. In addition, providing projects with different minimum investment amounts may help to include lower-income households. It is also important to know that tenants and homeowners display a similar interest in CiFi PV. Project developers may want to consider this in their design and marketing decisions.

If energy citizenship is to be more than an abstract academic concept but something actionable, it is essential to understand what citizens perceive as realist, accessible, and impactful forms of participation [40, 65]. Otherwise, citizens are more likely to identify as *"jilted energy citizens"* [37], responsible for enacting solutions to planetary destruction but without actual possibilities to engage with this responsibility meaningfully [65]. Community energy initiatives, for example, might not necessitate individual economic purchase power but rather require human capital resources, such as time and cognitive skills [13, 66]. This can also lead to the exclusion of certain citizens to participate in such initiatives. Providing clarity on these aspects could offer valuable insights for policymakers to determine whether energy citizenship can be put into action to engage a broader population in public initiatives like transforming the energy system.

Abbreviations

CiFi PV	Citizen-financed photovoltaics
DV	Dependent variable
IV	Independent variable(s)
PCA	Principal component analysis
PV	Photovoltaics

SHEDS Swiss Household Energy Demand Survey
SME Small- and medium-sized enterprises

Acknowledgements
We thank Marilou Jobin for her contributions to conceptualizing the study design and support during the data analysis. We thank Petra Moog for her helpful advice regarding the method and data analysis, as well as Christian Hertach for his contribution to the descriptive analysis. We are grateful to Corinne Moser and Michael Stauffacher for their critical reflections on this paper, as well as Sarah Heidenreich and Govert Valkenburg for inspiring discussions around (material) energy citizenship.

Author contributions
FS: methodology, survey design, data collection, data analysis, original manuscript draft, table preparations. FS and YB: conceptualization of study, discussion of results, conceptualization of original manuscript draft. YB: feedback on survey design, revision, editing and writing of manuscript sections. Both authors have read and agreed to the published version of the manuscript.

Funding
Open access funding provided by ZHAW Zurich University of Applied Sciences The Swiss Federal Office of Energy supported this work [Grant number SI/502195-01, 2020-2023].

Availability of data and materials
The data sets used and/or analyzed within this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study has been approved by the ZHAW School of Management and Law Ethics Committee and the ETH Zurich Ethics Commission. The research participants have been informed of the aims of this research and consented to the use of survey data for publication. All data has been collected anonymously.

Consent for publication
Not applicable.

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

Author details
[1]ZHAW, School of Management and Law, Institute of Innovation and Entrepreneurship, Theaterstrasse 17, 8401 Winterthur, Switzerland. [2]Department of Environmental Systems Science, Transdisciplinarity Lab, ETH Zurich, Universitätstrasse 22, 8092 Zurich, Switzerland.

Received: 25 September 2023 Accepted: 1 June 2024
Published online: 11 June 2024

References

1. Holden E, Linnerud K, Rygg BJ (2021) A review of dominant sustainable energy narratives. Renew Sustain Energy Rev 144:110955. https://doi.org/10.1016/j.rser.2021.110955
2. Vasileiadou E, Huijben JCCM, Raven RPJM (2016) Three is a crowd? Exploring the potential of crowdfunding for renewable energy in the Netherlands. J Clean Prod 128:142–155. https://doi.org/10.1016/j.jclepro.2015.06.028
3. Campos I, Marín-González E (2020) People in transitions: energy citizenship, prosumerism and social movements in Europe. Energy Res Soc Sci 69:101718. https://doi.org/10.1016/j.erss.2020.101718
4. Schwanitz VJ, Wierling A, Arghandeh Paudler H et al (2023) Statistical evidence for the contribution of citizen-led initiatives and projects to the energy transition in Europe. Sci Rep 13:1–9. https://doi.org/10.1038/s41598-023-28504-4
5. Sovacool BK, Dworkin MH (2015) Energy justice: conceptual insights and practical applications. Appl Energy 142:435–444. https://doi.org/10.1016/j.apenergy.2015.01.002
6. Szulecki K (2018) Conceptualizing energy democracy. Environ Polit 27:21–41. https://doi.org/10.1080/09644016.2017.1387294
7. Bauwens T (2020) When community meets finance. Nat Energy 5:119–120. https://doi.org/10.1038/s41560-019-0547-3
8. Bauwens T, Devine-Wright P (2018) Positive energies? An empirical study of community energy participation and attitudes to renewable energy. Energy Policy 118:612–625. https://doi.org/10.1016/j.enpol.2018.03.062
9. Berka AL, Creamer E (2018) Taking stock of the local impacts of community owned renewable energy: a review and research agenda. Renew Sustain Energy Rev 82:3400–3419. https://doi.org/10.1016/j.rser.2017.10.050
10. Knauf J, Wüstenhagen R (2023) Crowdsourcing social acceptance: why, when and how project developers offer citizens to co-invest in wind power. Energy Policy 173:113340. https://doi.org/10.1016/j.enpol.2022.113340
11. Bourcet C, Bovari E (2020) Exploring citizens' decision to crowdfund renewable energy projects: quantitative evidence from France. Energy Econ 88:104754. https://doi.org/10.1016/j.eneco.2020.104754
12. Stauch A, Vuichard P (2019) Community solar as an innovative business model for building-integrated photovoltaics: an experimental analysis with Swiss electricity consumers. Energy Build 204:109526. https://doi.org/10.1016/j.enbuild.2019.109526
13. Bauwens T, Schraven D, Drewing E et al (2022) Conceptualizing community in energy systems: a systematic review of 183 definitions. Renew Sustain Energy Rev. https://doi.org/10.1016/j.rser.2021.111999
14. Koch J, Christ O (2018) Household participation in an urban photovoltaic project in Switzerland: exploration of triggers and barriers. Sustain Cities Soc 37:420–426. https://doi.org/10.1016/j.scs.2017.10.028
15. Sierro F, Jobin M, Moser C, Blumer Y (2023) UNLOCK-PV: Die Rolle innovativer Investitionsmodelle in PV zur Beschleunigung der Energiewende. Bundesamt für Energie. https://www.aramis.admin.ch/Default?DocumentID=70581&Load=true
16. Fleiss E, Hatzl S, Seebauer S, Posch A (2017) Money, not morale: the impact of desires and beliefs on private investment in photovoltaic citizen participation initiatives. J Clean Prod 141:920–927. https://doi.org/10.1016/j.jclepro.2016.09.123
17. Reinsberger K, Posch A (2014) Bottom-up initiatives for photovoltaic: Incentives and barriers. J Sustain Dev Energy Water Environ Syst 2:108–117. https://doi.org/10.13044/j.sdewes.2014.02.0010
18. Braito M, Flint C, Muhar A et al (2017) Individual and collective socio-psychological patterns of photovoltaic investment under diverging policy regimes of Austria and Italy. Energy Policy 109:141–153. https://doi.org/10.1016/j.enpol.2017.06.063
19. Hatzl S, Seebauer S, Fleiß E, Posch A (2016) Market-based vs. grassroots citizen participation initiatives in photovoltaics: a qualitative comparison of niche development. Futures 78–79:57–70. https://doi.org/10.1016/j.futures.2016.03.022
20. Yildiz Ö (2014) Financing renewable energy infrastructures via financial citizen participation—the case of Germany. Renew Energy 68:677–685. https://doi.org/10.1016/j.renene.2014.02.038
21. Silvast A, Valkenburg G (2023) Energy citizenship: a critical perspective. Energy Res Soc Sci 98:102995. https://doi.org/10.1016/j.erss.2023.102995
22. Ryghaug M, Skjølsvold TM, Heidenreich S (2018) Creating energy citizenship through material participation. Soc Stud Sci 48:283–303. https://doi.org/10.1177/0306312718770286
23. Wahlund M, Palm J (2022) The role of energy democracy and energy citizenship for participatory energy transitions: a comprehensive review. Energy Res Soc Sci 87:102482. https://doi.org/10.1016/j.erss.2021.102482
24. Devine-Wright P (2007) Energy citizenship: Psychological aspects of evolution in sustainable energy technologies. Fram Present Shap Future Contemp Gov Sustain Technol 63–86
25. Lennon B, Dunphy N, Gaffney C et al (2020) Citizen or consumer? Reconsidering energy citizenship. J Environ Policy Plan 22:184–197. https://doi.org/10.1080/1523908X.2019.1680277
26. Lowitzsch J, Hoicka CE, Van Tulder FJ (2020) Renewable energy communities under the 2019 European Clean Energy Package—Governance

model for the energy clusters of the future? Renew Sustain Energy Rev 122:109489. https://doi.org/10.1016/j.rser.2019.109489
27. Caramizaru A, Uihlein A (2020) Energy communities: an overview of energy and social innovation. https://doi.org/10.2760/180576
28. Schreuer A (2016) The establishment of citizen power plants in Austria: a process of empowerment? Energy Res Soc Sci 13:126–135. https://doi.org/10.1016/j.erss.2015.12.003
29. Alegre I, Moleskis M (2021) Beyond financial motivations in crowdfunding: a systematic literature review of donations and rewards. Voluntas 32:276–287. https://doi.org/10.1007/s11266-019-00173-w
30. Vuichard P, Stauch A, Wüstenhagen R (2021) Keep it local and low-key: social acceptance of alpine solar power projects. Renew Sustain Energy Rev 138:110516. https://doi.org/10.1016/j.rser.2020.110516
31. Ebers Broughel A, Hampl N (2018) Community financing of renewable energy projects in Austria and Switzerland: profiles of potential investors. Energy Policy 123:722–736. https://doi.org/10.1016/j.enpol.2018.08.054
32. Schall DL (2020) More than money? An empirical investigation of socio-psychological drivers of financial citizen participation in the German energy transition. Cogent Econ Finance. https://doi.org/10.1080/23322039.2020.1777813
33. Kalkbrenner BJ, Roosen J (2016) Citizens' willingness to participate in local renewable energy projects: the role of community and trust in Germany. Energy Res Soc Sci 13:60–70. https://doi.org/10.1016/j.erss.2015.12.006
34. Dóci G, Vasileiadou E (2015) "Let's do it ourselves" Individual motivations for investing in renewables at community level. Renew Sustain Energy Rev 49:41–50. https://doi.org/10.1016/j.rser.2015.04.051
35. Radtke J (2014) A closer look inside collaborative action: civic engagement and participation in community energy initiatives. People Place Policy Online 8:235–248. https://doi.org/10.3351/ppp.0008.0003.0008
36. Mullally G, Dunphy N, O'Connor P (2018) Participative environmental policy integration in the Irish energy sector. Environ Sci Policy 83:71–78. https://doi.org/10.1016/j.envsci.2018.02.007
37. Throndsen W, Ryghaug M (2015) Material participation and the smart grid: exploring different modes of articulation. Energy Res Soc Sci. https://doi.org/10.1016/j.erss.2015.08.012
38. Marres N (2012) Material participation: technology, the Environment and Everyday Publics. Basingstoke: Palgrave Macmillan. https://link.springer.com/book/10.1057/9781137029669
39. Dunphy NP, Lennon B (2022) Whose transition? A review of citizen participation in the energy system. Routledge handbook of energy transitions, 1st edn. Routledge, London, pp 430–444
40. Palm J, Ambrose A (2023) Exploring energy citizenship in the urban heating system with the 'Walking with Energy' methodology. Energy Sustain Soc 13:11. https://doi.org/10.1186/s13705-023-00393-5
41. Felt U (2017) The handbook of science and technology studies, 4th edn. The MIT Press, Cambridge
42. Devine-Wright P (2007) Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. School of Environment and Development, University of Manchester. http://www.sed.manchester.ac.uk/research/beyond_nimbyism/
43. Sovacool BK (2016) How long will it take? Conceptualizing the temporal dynamics of energy transitions. Energy Res Soc Sci 13:202–215. https://doi.org/10.1016/j.erss.2015.12.020
44. Noppers EH, Keizer K, Bolderdijk JW, Steg L (2014) The adoption of sustainable innovations: driven by symbolic and environmental motives. Glob Environ Change 25:52–62. https://doi.org/10.1016/j.gloenvcha.2014.01.012
45. Noppers EH, Keizer K, Milovanovic M, Steg L (2016) The importance of instrumental, symbolic, and environmental attributes for the adoption of smart energy systems. Energy Policy 98:12–18. https://doi.org/10.1016/j.enpol.2016.08.007
46. Weber S, Burger P, Farsi M, et al (2017) Swiss Household Energy Demand Survey (SHEDS): Objectives, design, and implementation. SCCER CREST. https://www.sccer-crest.ch/fileadmin/FILES/Research/Weber_Burger_et_al_2017_SHEDS_Official_description.pdf
47. Sonnberger M, Ruddat M, Arnold A et al (2021) Climate concerned but anti-nuclear: exploring (dis)approval of nuclear energy in four European countries. Energy Res Soc Sci. https://doi.org/10.1016/j.erss.2021.102008
48. Schmid B, Meister T, Klagge B, Seidl I (2020) Energy cooperatives and municipalities in local energy governance arrangements in Switzerland and Germany. J Environ Dev 29:123–146. https://doi.org/10.1177/1070496519886013
49. Meister T, Schmid B, Seidl I, Klagge B (2020) How municipalities support energy cooperatives: survey results from Germany and Switzerland. Energy Sustain Soc 10:18. https://doi.org/10.1186/s13705-020-00248-3
50. Schmidt T, Stadelmann-Steffen I, Dukan M, et al (2023) Quantifying the degree of fragmentation of policies targeting household solar PV in Switzerland. 37 p. https://doi.org/10.3929/ETHZ-B-000596612
51. Karneyeva Y, Wüstenhagen R (2017) Solar feed-in tariffs in a post-grid parity world: the role of risk, investor diversity and business models. Energy Policy 106:445–456. https://doi.org/10.1016/j.enpol.2017.04.005
52. Blumer YB, Mühlebach M, Moser C (2014) Why some electricity utilities actively promote energy efficiency while others do not—a Swiss case study. Energy Effic 7:697–710. https://doi.org/10.1007/s12053-013-9249-z
53. European Commission (2024) Distribution of population by tenure status, type of household and income group—EU-SILC survey
54. Backhaus K, Erichson B, Weiber R (2011) Fortgeschrittene multivariate analysemethoden (Advanced Multivariate Methods of Statistical Analysis)
55. Field A (2013) Discovering statistics using IBM SPSS statistics. SAGE Publications
56. Hyun M, Jordan JS (2020) Athletic goal achievement: a critical antecedent of event satisfaction, re-participation intention, and future exercise intention in participant sport events. Sport Manag Rev 23:256–270. https://doi.org/10.1016/j.smr.2019.01.007
57. Swiss Federal Statistical Office (2022) Durchschnittsalter der ständigen Wohnbevölkerung in der Schweiz von 2011 bis 2021 (Altersmedian in Jahren). In: Graph Online. https://de.statista.com/statistik/daten/studie/216782/umfrage/durchschnittsalter-der-bevoelkerung-in-der-schweiz/
58. Ozili PK (2022) The acceptable R-square in empirical modelling for social science research. SSRN Electron J. https://doi.org/10.2139/ssrn.4128165
59. Staveren IV (2001) Gender biases in finance. Gend Dev 9:9–17. https://doi.org/10.1080/13552070127734
60. Wemyss D, Lobsiger-Kägi E, Jud S, Cellina F (2023) Leveraging realities of saving energy at home: contributions of co-design to behavioural interventions. Energy Res Soc Sci 104:103258. https://doi.org/10.1016/j.erss.2023.103258
61. Priessner A, Sposato R, Hampl N (2018) Predictors of electric vehicle adoption: an analysis of potential electric vehicle drivers in Austria. Energy Policy 122:701–714. https://doi.org/10.1016/j.enpol.2018.07.058
62. Moser C, Blumer Y, Hille SL (2018) E-bike trials' potential to promote sustained changes in car owners mobility habits. Environ Res Lett 13:044025. https://doi.org/10.1088/1748-9326/aaad73
63. Warneryd M, Karltorp K (2020) The role of values for niche expansion: the case of solar photovoltaics on large buildings in Sweden. Energy Sustain Soc 10:7. https://doi.org/10.1186/s13705-020-0239-7
64. Fisher RJ (1993) Social desirability bias and the validity of indirect questioning. J Consum Res 20:303. https://doi.org/10.1086/209351
65. Lennon B, Dunphy NP, Sanvicente E (2019) Community acceptability and the energy transition: a citizens' perspective. Energy Sustain Soc. https://doi.org/10.1186/s13705-019-0218-z
66. Lode ML, te Boveldt G, Coosemans T, Ramirez Camargo L (2022) A transition perspective on Energy Communities: a systematic literature review and research agenda. Renew Sustain Energy Rev 163:112479. https://doi.org/10.1016/j.rser.2022.112479

Publisher's Note