Photovoltaic diffusion from the bottom-up: Analytical investigation of critical factors

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HIGHLIGHTS

- Integrated SWOT–AHP analysis on bottom-up initiatives for photovoltaic diffusion.
- Quantification of weighting factors based on expert judgments.
- Financial attractiveness and environmental aspects as key success factors.
- Interaction of social innovations with top-down policies.

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ABSTRACT

The objective of this paper is to systematically identify and assess critical factors, which foster or hinder the development of bottom-up initiatives in the diffusion of photovoltaics. Bottom-up initiatives are social innovations, which entail civil engagement in energy transition at a local or regional level, and are expected to play a growing role in the governance of local energy systems in Europe. A mixed design methodology is used to identify critical factors and assess their importance. This involves combining an analysis of strengths, weaknesses, opportunities and threats with an analytic hierarchy process. The findings indicate that successful initiatives are those which are able to draw upon substantial local public interest and trust in the new technology, and which manage to combine financial attractiveness with environmental concerns. The results make clear that the political context is also an extremely important success factor. Given the appropriate circumstances, such initiatives may make a significant contribution in the transition to a sustainable energy system, and thus prove useful in reaching European energy targets.

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1. Introduction

Technological innovation has often been seen as the main issue of concern when attempting to increase the amount of renewable electricity generation. To date, the majority of innovation studies have focused on market-based, technological innovation, largely designed with a view to raising competitiveness, rather than the generation of novel social innovations [1]. Over the last few years, there has been a growing interest in innovation that is less technical or top-down in nature, but which instead emerges from the bottom-up [2]. Such developments are often characterized as ‘social innovations’. For example, energy cooperatives and local ownership of renewable energy technologies are attracting increasing attention as social innovations capable of supporting the growing transition toward sustainable energy. Such a societal transition in energy systems may also lead to specific social transformations in those communities and neighborhoods affected [3]. With respect to the substantive distinction that may be made between social and technical innovations, Howaldt and Schwarz [4] state that ‘social innovations do not occur in the medium of technical artefacts but at the level of social practice’. Hence, social innovations are effectively ‘acts of change’ [5] and entail new societal practices, changes of attitude and, in particular, new forms of organization.

Bottom-up initiatives (BUIs) are one example of relevant social innovation. These comprise social movements and other forms of civil engagement in energy transition at a local or regional level. In fact, several communities and regions have formulated explicit policy goals as part of their wish to transform their community by establishing a self-sufficient energy system [6,7]. Bottom-up initiatives may adopt a great variety of organizational forms. For

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example, they may be voluntary associations, social enterprises, co-operatives, or informal community groups, etc. In Austria, different forms of photovoltaic-related BUIs have also been observed in recent years; e.g. farmers who form societies to collectively install and operate photovoltaics (PV) on their roofs [8], or municipalities which use roofs of public buildings for PV plants [9]. Some of these cases require that participants in BUIs themselves provide space for the plants. This automatically excludes those who wish to contribute, but lack suitable roofs or land. Other types of BUIs merely depend on some form of financial contribution. Considering the large diversity of possibilities available, and the relatively broad scope for public involvement, such BUIs can actually be important drivers in the diffusion of new and more efficient technologies [10].

The diffusion of new and more efficient technologies, and thus the increased usage of renewable energy sources, has also been one of the main issues of concern within the energy policy of the European Union. For example, in accordance with [11], renewable energy sources are to be promoted in the internal electricity market. All national member states have thus been required to commit to specific targets for renewable energy production, consistent with the European Commission’s overall target of 20% of electricity produced from renewable energy sources by 2020. Other countries such as the USA and Japan have similar objectives. The national target for Austria was set at a share of 34% of energy generated from renewable sources in gross final energy consumption. Looking at the present situation in Austria, we see that this share was already 32.1% in 2012 but that growth has tended to slow down in more recent years [12]. This implies that Austria needs to maintain its effort if it is still to attain the national target of 34% by 2020. In view of the above mentioned energy targets, photovoltaic technology is believed (for several reasons) to be a promising approach in raising the amount of energy produced with renewables [13,14]. Should present global trends in PV expansion continue – PV is now enjoying a growth rate of 25–40% and is the fastest growing renewable energy source worldwide, and module prices continue to fall – the need for current subsidies is likely to disappear in the near future. The fact that small PV plants are not much less cost efficient than large ones (low economies of scale) provides an additional advantage in the spread of this technology. Growth potentials of alternative low-carbon energies often are limited by e.g. the non-availability of rivers for hydro power plants, scarcity of biomass or public resistance to wind parks and nuclear power plants. In Austria, PV technology plays a crucial role in the transition toward a sustainable energy system. Although electricity generation from photovoltaics in Austria makes up only a small percentage of total capacity, experts continue to view the growth potential of PV as being rather bright [15,16]. While in Austria the economic feasibility is still to a certain degree dependent on the prevailing funding scheme (feed-in tariffs for plants >5 kWp), the attractiveness of the technology continues to rise as PV electricity generation costs fall [17,18]. For plants >5 kWp the Austrian Eco Electricity Act (‘Ökostromgesetz’) guarantees feed-in tariffs (around 13 euro cents/kWh in 2014) for 13 years. This financial support helps community-based PV plants to break even even after 10–12 years. Also, with respect to photovoltaic technology, Maruyama et al. [19] argue that citizens play a significant role in the introduction of PV systems. The technology is not merely a question of introducing new equipment. It also frequently entails changes in environmental awareness, behavior and attitudes [20].

The origins of citizen power plants are mainly rooted in grassroots innovations. Seyfang and Smith [21] describe grassroots innovations as ‘networks of activists and organizations generating novel bottom-up solutions for sustainable development’. This includes solutions that respond to the local situation and to the interests and values of the communities involved. They argue that ‘in contrast to mainstream business greening, grassroots initiatives operate in civil society arenas and involve committed activists experimenting with social innovations as well as using greener technologies’.

Within the context of social innovations, grassroots innovations are based on innovative niche-based approaches designed to improve the involvement of people at the community level. These initiatives are driven by the idea of developing social structures and the capacity to build resilience at a community level. Moreover, they focus on two key-goals: The first is to satisfy the needs of those people or communities who may in some way be disadvantaged by, or excluded from, the mainstream market economy. In the case of PV, for example, this involves people without suitable roofs for individual PV panel installation and usage. The second goal is to build up ideological commitment so as to develop alternatives to the mainstream hegemonic regime [2].

However, while grassroots innovations are expected to play a growing role in the governance of local energy systems, little is actually known about the impact they have on policy processes and about the diffusion process of the technology [22]. Based on earlier debate, this paper argues that the mainstream perspective of innovations outlined above fails to acknowledge the contribution of social innovations, which can in fact be significant. Our study thus focuses on one type of grassroots innovation as a particular form of social innovation, i.e. bottom-up initiatives for PV diffusion.

The main objective of this paper is to systematically identify and assess the critical factors, which foster or hinder the development of BUIs for PV diffusion in Austria. Of special interest is, how such BUIs characterize their internal key elements, and how they interact with elements in the external environment, such as the existing (top-down) energy policies or market structures.

To address these questions, we identified crucial factors by means of a mixed method design, and quantitatively weighted them using the hybrid method of a SWOT analysis (strengths, weaknesses, opportunities and threats) and an analytic hierarchy process (AHP). To our knowledge, such an approach has not yet been taken. We thus believe this to be the first study to apply an integrated SWOT–AHP analysis to the context of social innovations. This approach provides us with a more holistic view of such a context and shows us how domain-specific professionals evaluate the prospects and challenges of PV bottom-up initiatives.

The remainder of the paper is structured as follows: In the next section, we present our method in detail. In Section 3, we systematically discuss the results of our SWOT–AHP analysis, as well as additional comments provided by participants in our study. In Section 4, we present conclusions from our study and implications for the role BUIs may play in a transformation of the current energy system into a more decentralized system with a higher share of renewables.

2. Method: SWOT and AHP

We apply an integrated SWOT–AHP analysis. This approach was first introduced by Kurttila et al. [23] in order to increase the effectiveness of a primary SWOT analysis as a decision-making tool. Due to the fact that the SWOT represents a mere qualitative analysis, the combination with the AHP makes the comparison of the alternatives more commensurable. This hybrid method has already been successfully applied in the energy sector, for example, in the context of agricultural biogas plants [24], energy management in paper and pulp companies [25], and in the role of photovoltaics in energy transition [16].

In order to apply this hybrid method, we implemented a two-stage study design. In the first stage, we identified potential
strengths, weaknesses, opportunities and threats (SWOT) related to the diffusion of PV bottom-up initiatives in Austria. In the second stage, the most relevant strengths, weaknesses, opportunities and threats are quantitatively assessed by professionals (AHP).

To identify the most relevant SWOT factors for our analysis, a list of factors considered to either hinder or foster PV-BUI diffusion was first compiled. This drew on a review of existing scientific literature (e.g. [26,27]) and on a qualitative and quantitative analysis of empirical data. In this way a comprehensive list containing the most relevant factors for BUIs was drawn up for SWOT analysis. The qualitative data was collected from semi-structured interviews conducted with key-actors in the field of BUI for photovoltaics. Between June 2013 and April 2014, 7 interviews with experts in the field of PV (e.g. energy providers, politicians, practitioners, consultants, etc.) were conducted in order to gather general information about BUI development from an external, meta-perspective (e.g. funding scheme, market development, barriers and drivers for diffusion). Subsequently, 16 interviews with key actors – persons who have played a major role in the founding process of different BUIs in Austria – were conducted. The purpose was to gain insights and knowledge about internal BUI characteristics (founding process, actor constellation, structure and organization) based on individual experiences of key-actors. Owing to the fact that no comprehensive information on BUI characteristics was available for Austria, a process of theoretical sampling was used to select interviewees. Previous studies, as well as a web search, indicated that various forms of PV-BUIs existed in Austria. These were to differ in terms of their business and/or financial model, their goals, number of adopters, location in Austria, etc. The first group of interviewees was selected based on a web search. In selecting further interviewees we aimed at obtaining a broad variety of Austrian BUIs covering most of the mentioned characteristics. The number of interviews was not determined a priori but by a process of theoretical saturation, i.e. data collection stopped when no additional useful information appeared to be forthcoming. As mentioned above, the results of a quantitative survey (n = 870), carried out between April and June 2014, were drawn upon in order to aid SWOT factor identification. This survey involved two best-practice BUIs in Upper Austria, and provided insights into the relevant motives (economic, social, ecological) of those who participated in these initiatives, or those who deliberately chose not to participate. This survey also provided us with further useful evidence concerning experiences, interests and expectations relating to BUIs.

After compiling the list, those aspects applicable to most of the different BUI designs in Austria were selected. Owing to reasons of methodology, not all possible SWOT factors can be considered for processing with AHP. Saaty [28] suggests using only a small number of factors in order to keep the calculative effort to a manageable level. As a consequence, three aspects per SWOT category were selected, based on the frequency with which they are mentioned in the literature, in interviews and in the survey. In order to validate the SWOT factor selection, workshops were arranged with key-actors from two BUIs. Here, the SWOT factors identified were then discussed and their definitions refined. For this purpose, a focus group design was applied and a guideline for moderating group discussion was prepared. This was intended to ensure that the proposed SWOT factors and the respective categories were understandable, relevant and applicable for BUIs in Austria. Moreover, a short description of each SWOT factor element was also added so as to ensure common understanding, particularly with regard to SWOT factor weighting.

The second stage of the method implies a pairwise comparison and weighting of the SWOT factors, which was done by using an online questionnaire (Limesurvey). After a pre-test, the questionnaire was distributed between December 2014 and January 2015 to 121 professionals in the field of PV bottom-up initiatives in Austria, i.e. to 67 energy experts, and to 54 founders of PV bottom-up initiatives in Austria. The 67 energy experts, all with an extensive background in photovoltaics and citizen participation models, comprised academics (scientific researchers and consultants), practitioners (plant operators and planners, energy providers), as well as policy makers and representatives from various interest groups. The selection of the specialists for the survey was guided by the desire to provide a holistic view of the current situation regarding the diffusion of BUIs in Austria; an internal view from BUI founders (BUIF), and an external view from energy experts (EE). The questionnaire was returned by 23 founders (response rate: 42.6%) and by 29 energy experts (response rate: 43.3%). We are aware of the fact that such an approach is always subject to limitations and potential bias. Nevertheless, we believe we were able to achieve a well-balanced sample (n = 52) in this study, sufficiently representative of diverse backgrounds and variance in evaluation.

Completion of the questionnaire entailed pairwise comparison of individual SWOT factors with other factors in the same SWOT category (S a to S b, S a to S c, S b to S c, etc.), as well as subsequent cross-category comparison (S to W, S to O, etc.). For all the comparisons we applied a nine-step scale suggested by Saaty [29] which ranges from 9:1 (meaning that factor a is much more important than b) to 1:9 (meaning that factor b is much more important than factor a). The even numbers were deliberately left out as intermediate steps. The center of the scale (1:1) indicated that the respective factors were considered to be of equal importance.

After all the factors were weighted by the two groups of professionals, the relative priority level p(0 < p < 1, \sum_i^n p_i = 1) for each of the SWOT factors in a group of n factors was calculated using the eigenvalue method [30,28]. First of all, the local factor priority \( p(f) \) – the relative importance of each factor based on the average values of the professional comparisons of the factors within the same SWOT category – was determined. In addition, we calculated the group priority level \( p(g) \) – the relative importance of each of the respective SWOT categories. Finally, we computed the global factor priority \( gp(f) \) for every individual SWOT factor by multiplying the local factor priority by the respective group priority.

According to Saaty [29] the consistency of the expert judgements can be tested by evaluating the consistency ratio (CR). As a rule of thumb, CR should be below 10%, otherwise inconsistent judgements have been made. It turned out that one respondent in the group of energy experts had made inconsistent judgments, resulting in a CR above 10% for the comparison of strengths. We consequently removed all judgments made by this respondent. The judgments of the remaining sample showed sufficient consistency, as indicated by CRs below 10% for all comparisons.

3. Results and discussion

3.1. Strengths, weaknesses, opportunities and threats

In the process outlined in Section 2 we were able to identify 15 possible strengths, 7 possible weaknesses, 8 potential opportunities, and 7 potential threats for the diffusion of PV-BUIs in Austria. A full list of these factors is given in Supplement B.

After reducing the initial number of factors as described above, we ended up with a set of three factors per SWOT category. These factors were further processed via AHP based on a survey of professional opinion. A summary of the selected SWOT factors is presented in Table 1.

\footnote{Note: Only the most important concepts of the AHP method are presented here. A more detailed description is given in Supplement A.}
In the category of strengths, i.e. positive internal factors, we note that joining a PV BUI can be seen as a financially attractive investment. Rates of return are higher when compared to more conservative investment plans, and BUIs are considered a rather safe form of investment. Usually, the minimum investment starts at around 100 euros, and rates of return are between 3% and 3.6%. Moreover, BUIs contribute to environmental protection and to the reduction of greenhouse gas emissions, since PV causes no emissions during operation. Additionally, PV plants displace coal and gas plants from the markets through short and long term merit order effects [31]. Thus, PV BUIs may also contribute to a reduction in dependency on imported fossil sources.

With respect to weaknesses, i.e. negative internal factors, we note that considerable effort is required by founders in the start-up process. This not only includes dealing with several bureaucratic steps, but also in undertaking information and communication tasks with various stakeholders. Apart from that, uncertainties concerning the basic business model also remain. BUIs in the field of PV are rather new, and therefore the business model is not yet well established. A number of questions regarding legal and financial form remain open. It also has to be mentioned that PV plants are not yet economically feasible in Austria without the currently available public subsidies in the form of (capped) feed-in tariffs for plants above 5 kWp. Note that public support for roof-top PV is sometimes subject to criticism, since the beneficiaries are usually relatively wealthy, e.g. house owners who can easily afford the upfront costs. BUIs are less open to this critique since financial contributions can be relatively low, thus making it possible for less wealthy citizens to benefit from subsidies.

In the category of opportunities, i.e. positive external factors, we note that costs for PV are expected to decrease in comparison to other energy sources. Prices for panels are continuously falling, and solar radiation comes at no cost. Another opportunity appears in the form of rising awareness of PV BUIs among the population. The media report frequently on successful energy initiatives, word of mouth also plays a strong positive role, and in general, ecological investment appears to be gaining a much more positive image. We also recognized as an opportunity the fact that PV citizen power plants are gaining in significance in terms of policy strategy. This includes political support for renewables in general, and the implementation of respective strategies in legislation on the long run.

In the category of threats, i.e. negative external factors, we note a certain resistance with respect to the transformation of the dominant centralized structures in the energy sector toward a higher share of renewables, and a higher degree of decentralization. Energy and grid providers tend to prefer the status quo, and support existing business models. Additionally, economic and political conditions remain uncertain to a certain degree due to the economic and financial crisis. Reliable forecasts on future supply of and demand for renewable energy sources are lacking. Furthermore, there are legal and financial uncertainties related to the electricity grid, especially with respect to grid control, and to the expansion and maintenance of the current grid. The uncertainties mainly result from the fact that power output from photovoltaic energy fluctuates due to the intermittency of the solar irradiation.

This is perceived to have particularly negative implications for grid stability where photovoltaic represents a significant portion of electricity generation.

### 3.2. Analytic hierarchy process (AHP)

When comparing the judgments made by founders of initiatives with those of other experts in the field, we see some disagreement regarding the relative importance of different factors. This may be related to the fact that founders mainly know their own BUI, but do not have a macro-view of the experiences of other founders.

We also notice that BUI founders have stronger opinions regarding the relative priority of single factors. This means that those factors they consider most important receive higher relative weights compared to the assessments provided by other professionals.

In general, both participant pools agree that positive factors, i.e. strengths and opportunities in the SWOT terminology, dominate over negative factors, i.e. weaknesses and threats. Strengths receive a relative group priority of $p(S) = 0.40$ in the founders’ assessments, and $p(S) = 0.41$ in the other experts’ assessments. Opportunities are ranked second, at $p(O) = 0.25$, in founders’ assessments, and $p(O) = 0.31$ in other experts’ assessments. Weaknesses and threats were given relatively low priorities, with respective values for weaknesses being $p(W) = 0.19$ and $p(W) = 0.13$, and for threats $p(T) = 0.16$ and $p(T) = 0.15$.

Let us now look at the individual factors within the identified strengths. Interestingly, the two groups of experts hold different opinions on what is the most important BUI strength: While founders see $S_1$ the contribution to environmental and climate protection as the most important strength ($lp(S_1) = 0.41$), followed by $S_2$, i.e. the fact that BUIs represent a financially attractive investment for participants ($lp(S_2) = 0.33$), the energy experts state just the opposite with ($lp(S_1) = 0.41$, and $lp(S_2) = 0.35$). Thus, while founders seem to put more weight on underlying environmental attitudes, the energy experts largely recognize such initiatives as a financially attractive investment opportunity. One reason for this could be that founders see things from a more personal point of view, and perceive environmental benefits to be the key sales argument. In contrast, energy experts adopt a more neutral stance and are likely to evaluate strengths based more directly on utility. In addition, while the annual income generated by BUIs is a clear tangible advantage, environmental or climate benefits are difficult to perceive and may thus be more difficult to acknowledge. This is also reflected in BUI marketing activities. These can take many different forms depending on which business model is chosen and on the interest rate on offer. Interviews revealed, for example, that when interest rates are rather low (<3.0%), key-actors recommend that BUIs focus on advertising their goals in terms of the associated environmental benefits, e.g. increased use of renewable energy, greater local production and value creation, etc.

The fact that such initiatives might contribute to reducing dependency on imports of fossil fuels for electricity generation received a relatively low priority within the group of strengths.
When it comes to BUI weaknesses, both participant groups agree on the ranking of the factor priorities. However, while the energy experts are rather indifferent and assign similar importance to all three factors, the founders identify \( W_a \) as the key weakness, i.e. the fact that currently economic feasibility is not possible without subsidies, giving it a priority figure of \( \text{Ip}(W_a) = 0.62 \). In contrast, expert assessment of this factor is \( \text{Ip}(W_a) = 0.36 \). Our qualitative data supports this ranking since the majority of key actors interviewed emphasizes that founding a BUI is not possible without subsidies. The respectively higher importance ascribed to this factor by founders is probably a reflection of their personal experience and involvement during the founding process. Thus, the founders seem to be much more worried about economic weaknesses than the experts who, it may be assumed, enjoy a more detached meta-view. The second most important weakness stated in the analysis is \( W_b \), i.e. the considerable effort required in establishing an initiative. The respective priority figures for the two groups were \( \text{Ip}(W_b) = 0.23 \) and \( \text{Ip}(W_b) = 0.34 \). Potential uncertainties concerning the business model, e.g. the legal and financial form of an emerging initiative \( W_a \), is considered to be the least relevant weakness in this analysis, with figures of \( \text{Ip}(W_a) = 0.15 \) and \( \text{Ip}(W_a) = 0.30 \), respectively.

Looking at the ranking of opportunities, we discover complete disagreement between the two participant pools. The factors are ranked in a different order, and again the founders identify one factor that is clearly more important than the others, while the energy experts identify only relatively minor differences. The most significant opportunity in the founders' assessment is \( O_a \), i.e. that photovoltaic bottom-up initiatives seem to be gaining importance in political strategies. The weighting here was \( \text{Ip}(O_a) = 0.48 \). The weighting for \( O_b \), the increasing awareness of PV BUIs in the population, was \( \text{Ip}(O_b) = 0.26 \), and that of \( O_c \), expected further reduction of PV costs when compared to competing energy sources, was \( \text{Ip}(O_c) = 0.25 \), i.e. they are considered to be of relatively minor importance. In contrast, the energy experts consider \( O_c \), the increasing awareness of PV BUIs in the population, to be the most important opportunity at \( \text{Ip}(O_c) = 0.38 \), followed by \( \text{Ip}(O_b) = 0.34 \), the expected further reduction of PV costs. Interestingly, and in sharp contrast to the assessments of the founders, they hardly see \( O_a \), changes in political strategies, as a significant opportunity, giving it a relatively low factor priority of \( \text{Ip}(O_a) = 0.28 \). As a result of our interviews with key actors, we noticed that in the majority of cases, municipalities play a major role in the BUI founding process. Municipalities support key actors, e.g. by providing roof space or organizational aid. This may induce founders of PV initiatives to perceive their activities as contributing to the importance of PV-BUIs in political strategies (on a regional and national level).

We also find some disagreement when it comes to assessing the most significant threats to PV BUIs. In the founders' assessments, \( T_a \), uncertain economic and political conditions, turns out to be the most relevant threat, with \( \text{Ip}(T_a) = 0.49 \), followed by \( T_b \), resistance regarding the transformation of currently dominant structures in the energy sector, at \( \text{Ip}(T_b) = 0.30 \). In the energy experts' assessments, the picture is reversed. They see \( T_b \), dominant structures in the energy sector, as the main threat, with \( \text{Ip}(T_b) = 0.42 \), followed by uncertain political economic conditions, at \( \text{Ip}(T_b) = 0.30 \). The disagreement between energy experts and founders probably reflects the latters' experience in the process of BUI establishment. Interview data reveals that while some founders met with no resistance (or even with support) when founding their BUIs, others did not. In contrast, experts tend to emphasize the 'big picture' (i.e. energy supply companies will not allow a 'take-over' of BUIs, although they may be willing to tolerate limited BUI diffusion). The third threat, \( T_c \), legal and financial uncertainties, is ranked as the least relevant by both participant groups, with respective factor priorities of \( \text{Ip}(T_c) = 0.21 \) and \( \text{Ip}(T_c) = 0.28 \).

An interesting observation in the founders' group is the fact that the most important threat, as well as the most important opportunity are both related to political conditions. This probably reflects founders' experience of a high degree of dependence of BUI's success on prevailing politics and policies, and their positive and negative perceptions regarding related further development.

Finally, we calculate a global factor priority for each factor by multiplying the local factor priority by the respective group priority. In this analysis too, the positive factors dominate: the top 5 factors in the judgments of the energy experts are all related to strengths and opportunities, as are 4 of the top 5 factors in the judgments of the founders.

For the founders, the overall most important factor is \( S_b \), the contribution to environmental and climate protection, with \( \text{gp}(S_b) = 0.16 \), followed by \( S_a \), BUIs represent a financially attractive investment for participants, at \( \text{gp}(S_a) = 0.13 \). The picture is reversed for the energy experts, with financial attractiveness \( \text{gp}(S_a) = 0.17 \) taking the lead, followed by environmental protection \( \text{gp}(S_b) = 0.15 \).

In the founders' assessments the third most important factor overall is \( O_a \), photovoltaic bottom-up initiatives gaining importance in political strategies, while for the expert group it is \( O_b \), the increasing awareness of PV BUIs in the population.

The fourth most important factor for the founders is the weakness \( W_c \), lack of economic feasibility without subsidies, while for the energy experts it is the opportunity \( O_c \), an expected further reduction of PV costs. \( S_c \), reduced dependency on fossil fuels, ranks fifth in both groups' judgements.

The AHP results are presented in Table 2; consistency ratios (CR) for all comparisons are reported in Table 3. Figs. 1 and 2 illustrate the respective results graphically for the judgments made by founders and experts. Note that the length of the lines reflects the group priorities, while the data points relate to the global factor priorities.

### 3.3. Cross-category analysis

While AHP allows for a priority ranking of SWOT factors, it does not immediately suggest concrete strategies for PV bottom-up initiatives. We therefore undertook an additional cross-category analysis in order to identify more specifically the connections between strengths, weaknesses, opportunities and threats. Although the implementation of concrete strategies always needs to be geared to the initiative in question, such general analyses can still be helpful for strategy development. Table 4 summarizes the key outcomes.

A comparison of opportunities and strengths (O–S) deepens understanding of how opportunities may be capitalized upon in the face of the prevailing strengths. Factors currently favouring the spread of PV-BUIs in Austria are the high level of awareness among the general population and among decision makers, falling costs, and the associated environmental and financial benefits. One means of stressing the positive environmental effects of energy system transformation would be to make use of a 'CO\(_2\) avoidance counter', either on the respective BUI web page, or directly on the solar power plant itself.

A further aspect that needs to be mentioned is how weaknesses may be overcome so that the defined opportunities may be actualized (O–W). As mentioned above, PV-BUIs could benefit from the current social and political momentum if greater emphasis were to be placed on overcoming business model uncertainty and on lessening the effort required for start-up. For example, joint effort
Table 2: Final weight scores of the SWOT factors, separated into BUI founders (BUIF) and energy experts (EE).

<table>
<thead>
<tr>
<th>SWOT factors</th>
<th>BUIF group priority</th>
<th>EE group priority</th>
<th>BUIF local priority</th>
<th>EE local priority</th>
<th>BUIF global priority</th>
<th>EE global priority</th>
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<td>S1</td>
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<tr>
<td>S4</td>
<td>0.15</td>
<td>0.30</td>
<td>0.15 (3)</td>
<td>0.30 (3)</td>
<td>0.03 (12)</td>
<td>0.04 (12)</td>
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<tr>
<td>W4</td>
<td>0.25</td>
<td>0.31</td>
<td>0.25 (3)</td>
<td>0.34 (2)</td>
<td>0.06 (8)</td>
<td>0.10 (4)</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O1</td>
<td>0.25</td>
<td>0.31</td>
<td>0.25 (3)</td>
<td>0.34 (2)</td>
<td>0.06 (8)</td>
<td>0.10 (4)</td>
</tr>
<tr>
<td>O2</td>
<td>0.26</td>
<td>0.38</td>
<td>0.26 (2)</td>
<td>0.38 (1)</td>
<td>0.07 (7)</td>
<td>0.12 (3)</td>
</tr>
<tr>
<td>O3</td>
<td>0.48</td>
<td>0.28</td>
<td>0.48 (1)</td>
<td>0.28 (3)</td>
<td>0.12 (3)</td>
<td>0.09 (6)</td>
</tr>
<tr>
<td><strong>Threats</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>0.16</td>
<td>0.15</td>
<td>0.30 (2)</td>
<td>0.42 (1)</td>
<td>0.05 (9)</td>
<td>0.06 (7)</td>
</tr>
<tr>
<td>T2</td>
<td>0.49</td>
<td>0.30</td>
<td>0.49 (1)</td>
<td>0.30 (2)</td>
<td>0.08 (6)</td>
<td>0.04 (10)</td>
</tr>
<tr>
<td>T3</td>
<td>0.21</td>
<td>0.28</td>
<td>0.21 (3)</td>
<td>0.28 (3)</td>
<td>0.03 (11)</td>
<td>0.04 (11)</td>
</tr>
</tbody>
</table>

Table 3: Consistency ratio (CR) for comparisons of SWOT groups with other SWOT groups, and for factor comparisons within the SWOT groups. Note that the CR is below 10% for all comparisons, indicating sufficient consistency in the judgments of the participants.

<table>
<thead>
<tr>
<th>Group comparison</th>
<th>Within-group comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWOT groups (%)</td>
<td>Strengths (%)</td>
</tr>
<tr>
<td>BUIF</td>
<td>1.79</td>
</tr>
<tr>
<td>EE</td>
<td>0.30</td>
</tr>
</tbody>
</table>

3.4. Factors additionally mentioned by respondents

After doing the pairwise comparison of the factors in each SWOT category, respondents were asked to name additional factors they consider of relevance. By this means we aimed to check for relevant factors that may have been overlooked, and to seek validation of those factors already selected. Here, 24 out of the 52 respondents provided at least one additional comment. The category ‘strengths’ received the highest number of additional comments (23), followed by ‘weaknesses’ (10), ‘opportunities’ (5) and ‘threats’ (4). To a large degree, the additional factors mentioned had already been included in the list of extended SWOT factors (Supplement B), or were in some way equivalent, and thus were deliberately excluded from AHP analysis. The strengths mentioned by respondents mainly related to social, financial and environmental factors, or to the regional character of many projects. For example, a number of respondents pointed out that these joint PV projects had the potential to strengthen social cohesion and community spirit, and to boost community identity. This factor had already been taken into account in the extended list and is clearly important in some initiatives. However, since it cannot be applied to the majority of the cases investigated, and in order to be in a position to offer a rather general perspective, we decided not to include it in the AHP analysis.

Some comments regarding additional strengths also relate to financial aspects, such as the high degree of transparency of the investment. In general, participating in a BUI is considered a safe and meaningful investment. Another reported strength is that participants may not need to provide their own space for PV modules, nor do they need to deal individually with bureaucratic processes when installing PV modules. Our survey findings also underline that participation in a BUI is mainly driven by environmental and...
financial intentions. Hence, these factors were considered to be less important than those chosen for AHP processing in the selection process.

Additional weaknesses mentioned by the respondents involve mainly legal and minor operative aspects. However, most of these comments are unlikely to hold when subject to an objective investigation. For example, the fact that suitable roof space is relatively scarce. According to the key actors interviewed, however, capacity continues to grow in Austria as the public acceptance of such initiatives rises, and it is simply a question of matching demand and supply.

Additional comments mentioned concerning opportunities and threats were mostly already covered by the selected SWOT factors and thus did not point to anything new or relevant (e.g. the positive image of PV (O), legal restrictions concerning the business model or various aspects of planning (T), decreasing support for PV due to global political and economic developments (T), etc.).

Bearing in mind also the supportive literature and data (interviews and survey) employed in the selection process, we may safely conclude that our initial list of SWOT factors covers a large part of the potential strengths, weaknesses, opportunities and threats concerning the prospects of PV BUIs. The interview comments also serve to corroborate our initial selection of SWOT factors for AHP processing, since no new substantial factors were mentioned.

3.5. Limitations

The methods used and the results presented here are still subject to several limitations. For example, our analysis focuses on PV bottom-up initiatives in Austria in general, and not on specific initiatives, which in practice may take a variety of different forms. While our assessment of factors may still serve as a basis for strategy development for single BUIs, it is likely that specific local adaptations will be needed. We thus refrain from ranking possible strategies, and merely offer a qualitative reflection in Section 3.3.

In a similar vein, while we do not wish to presume universal validity for our results, we do believe that the results nevertheless indicate propensities relevant for BUI implementation.

Another limitation is that not all of the identified SWOT factors could be integrated in AHP, and thus only the selected factors could be ranked on a quantitative basis.

We also note that unlike the level of integration possible in an Analytic Network Process (ANP) [32,33], the AHP approach chosen here does not account for interdependencies of the SWOT factors. Nevertheless, AHP was selected for the present study because is
a useful tool for converting perceptions into quantifiable form, and also because it allows for the number of necessary pair-wise comparisons to be kept at a manageable level for participants. This meant that the value gained through access to an adequately large and diverse participant pool outweighed the value that would have been gained through the utilization of ANP.

4. Conclusions

The results of our SWOT/AHP analysis indicate that both the founders of PV initiatives, as well as experts in the energy sector, appear to be rather optimistic regarding the future prospects for bottom-up initiatives designed to support PV adoption. The current financial attractiveness of such projects, together with their potential contribution to environmental and climate protection are seen as key success factors. With respect to attracting potential participants, the combination of green values with the possibility to invest money on attractive terms seems to be a compelling sales argument, and definitely helps in the diffusion of such business models. The current high degree of public mistrust in banks and public authorities further supports people’s willingness to participate in community-scale investment projects.

However, the combination of green values with financial profit also involves one, easily neglected, drawback: Whenever market values enter an arena that previously has been shaped by idealism and strong moral values, market values tend to replace or undermine moral considerations. There is thus a risk that financial

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**Table 4**

<table>
<thead>
<tr>
<th>External factors</th>
<th>Internal factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strengths (S)</td>
<td>Weaknesses (W)</td>
</tr>
<tr>
<td>(Sₐ)</td>
<td>(Wₐ)</td>
</tr>
<tr>
<td>(Sₐ)</td>
<td>(Wₐ)</td>
</tr>
<tr>
<td>(Sₐ)</td>
<td>(Wₐ)</td>
</tr>
<tr>
<td>Opportunities (O)</td>
<td>Establish ‘umbrella’ association</td>
</tr>
<tr>
<td>(Oₐ) Concentrate marketing on positive effects for environment and energy system</td>
<td></td>
</tr>
<tr>
<td>(Oₐ)</td>
<td>(Oₐ)</td>
</tr>
<tr>
<td>Threats (T)</td>
<td>T–S Strategy</td>
</tr>
<tr>
<td>(Tₐ) Stimulate active participation to further increase relevance of BUIs</td>
<td></td>
</tr>
<tr>
<td>(Tₐ)</td>
<td>T–W Strategy</td>
</tr>
<tr>
<td>(Tₐ) Develop robust business models</td>
<td></td>
</tr>
</tbody>
</table>

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**Fig. 2.** Graphical representation of the global and the group priority, showing energy experts’ preferences with respect to PV BUIs.
considerations might crowd out ethical, moral, or in our case, environmental values. This possibility is well supported by the literature in behavioral economics [34,35], but is often not adequately considered by the actors in the field. Currently, founders still seem be driven by a great deal of idealism, as reflected by the top ranking given to environmental values in their AHP assessments. On the other hand, the experts employing a more meta-level perspective clearly place financial aspects above environmental aspects in their assessments. Economic considerations can be expected to become even more dominant as these initiatives move from a niche existence to a more mainstream domain. One could argue that idealism begins to lose relevance once these initiatives enter the mainstream. However, if idealism is choked off by market norms prematurely, such initiatives might never overcome their niche existence in the first place.

Bearing this in mind, it becomes clear that the political context is extremely important in the success of such initiatives. Leaving idealism and general goodwill aside, bottom-up initiatives can be seen as a collective reaction to a specific governmental top-down policy, i.e. to the guaranteed feed-in tariffs for electricity generated from renewables. Although module prices continue to fall, and grid-parity is expected to be reached soon, PV plants in Austria still rely on this form of public support. Projects in the short-term and mid-term future are to a great extent dependent on a continuation of public subsidies, both on their amounts, and on their respective time-horizons. Thus, in order that initiative planning may be improved, there is clearly a need for a more long-term funding strategy on the part of national authorities. Once BUIs are recognized as being a relevant contributor to climate and renewable energy targets, they need to be encouraged and bureaucratic processes simplified. Possible measures include establishing one central contact point for BUIs in order to help overcome current weaknesses, such as the considerable effort required in the founding process. Additionally, greater focus could be placed on addressing current challenges with regard to the selection of appropriate business models and on dealing with legal issues.

Lack of interest in the technology, or lack of governmental support are not the problem at all. On the contrary, PV is considered to be a well-accepted technology in Austria [16], governmental support is also appreciated by large parts of the population, and willingness to adopt PV, as expressed in the form of installation of roof-mounted modules or participation in BUIs, seems to be rather high. BUIs continue to receive a high number of requests for membership. It would also appear that engaging in alternative forms of investment seems to become more popular in times of economic and financial crisis. In this context, BUIs kill two birds with one stone in that they address public demand for safe and meaningful investments, while also contributing to official environmental and energy targets in the diffusion of green technologies.

In that sense, social innovations particularly in the form of grassroots innovations respond to the local situation and thus to the interests and values of the participants or communities involved. Building up more resilient structures by using decentralized, efficient and green technologies as photovoltaics from the bottom-up contributes not only to an increase in the usage of renewables in Austria, but also to yield the overall European energy targets.

New opportunities for bottom-up cooperation between governments, stakeholders and the general public are emerging all the time. Any insights gained in such fields are likely to motivate more and more regional planners, entrepreneurs and national policy authorities to become engaged in the process of energy transition.

Acknowledgements

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Supplementary A and B

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.apenergy.2015.08.117.

References


