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Article

Organizational Challenges in the Adoption of Building Applied Photovoltaics in the Swedish Tenant-Owner Housing Sector

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Abstract: Sweden has committed itself to comply with EU-directive 2009/28/EC on energy from renewable sources and 2012/27/EU on improvement in the efficiency of energy. Measures in the existing housing stock, such as installing photovoltaics (PV), provide a means of contributing to the goals above. The purpose of this paper is to study how the organization of property management and the decision-making structure in tenant-owner cooperatives (TOCs) in Sweden facilitates or hampers the adoption of large-scale residential building applied photovoltaics (BAPV) in this housing sector. Data collected through seven semi-structured interviews of executive board members in seven housing cooperatives were descriptively analyzed and the results indicate that the decision to adopt BAPV in TOCs does not follow the common frameworks of adoption of innovations. The choice by TOCs to adopt BAPV depends more on the wish to lower operating costs than on efforts to promote a sustainable environment and various principal-agency problems during the decision-making process, as well as during the implementation phase create challenges to the adoption of BAPV. There is a need to strengthen the quality and management of knowledge, as well as procurement proficiency in the TOCs in order to harness the potential for BAPV in the sector.

Keywords: energy-efficiency; BAPV; photovoltaic; housing cooperative; principal-agent; tenant-owner; incentive problems; Sweden

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1. Introduction

The Swedish parliament has committed itself to comply with European Union (EU) legislation and has incorporated several EU directives into Swedish law, such as the Renewables Directive 2009/28/EC [1], requiring 20% of all energy used in the EU to be from renewable sources by 2020. The Energy Efficiency Directive 2012/27/EU [2] aims to see a 17% improvement in the efficiency of energy use by 2020. An important means of achieving the goals above is to raise the energy efficiency levels of the existing building stock through measures applied during the refurbishment process [3–5]. The built environment and in particular the housing sector stands for about 38 percent of Sweden's energy consumption and the housing sector alone accounts for about 25% of all of the electricity consumption every year [6]. While, the price of electricity has continued to rise since 1999, there has been a sharp downward trend in the price of photovoltaic panels and, consequently, the cost of electricity from these units [7].

In Sweden, the tenant-owner cooperative (TOC) housing sector accounts for about 36% of the multi-family housing. Much of the stock is in need of energy efficiency measures, due to age and other problems typical for buildings from the period 1965–1974 in which one million dwellings of various tenure were constructed [3,8]. TOCs can lower their energy use by 20% by the year 2020 through a number of measures, such as adjustment of the heating system [9]. Installing building-applied photovoltaics (BAPV) at the same time as the renovation of the roof is taking place could provide a cost efficient access to a source of renewable energy for the TOC. Studies about investors in renewable electricity production show that there is a need for research on the motives for the investment, the background and personal characteristics of the investor/decision maker, and how this affects the decision [10]. The tenant-owner tenure form provides an interesting research area in the field of renewable energy sources and sustainable property management. It encompasses the wishes of the individual unit dweller, who is, at the same time, a shareholder in, and collectively responsible for the multiple unit multi-family property. Conflicting interests and agency-related incentive problems among different parties can affect the costs related to the investment as well as the willingness to carry out an investment. The adoption of large-scale residential BAPV presents several challenges for the non-professional decision maker sitting on the executive board of a tenant-owner cooperative housing association. There is a need to understand these problems if the potential for renewable energy from BAPV that is provided by the large roof space under the ownership of TOCs is to be utilized to the full.

An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of potential adoption [11]. The installation of BAPV by tenant-owner cooperatives is an innovation in that it replaces or compliments the electric system that has been in use in the sector for a very long time. An analysis of the procedure as well as the arguments that are taken into consideration before a decision to adopt an innovation is made, helps to clarify the reasons behind the choices made by the potential adopter [11–13]. Within office properties, potential adopters have been identified as those persons in a decision-making position in a project development organization who decide what technological innovations to incorporate in the construction of a new office building [14]. In a TOC, the acquisition of the BAPV system will depend on decisions of the members of the executive boards who, in this study are considered to be the "potential adopters".

Literature on the adoption of renewable energy technologies in the built environment covers various types of housing owners, buildings and properties, such as housing associations in the Netherlands [5,15];

public municipal housing companies in Sweden [3]; owner-occupier housing [16–19]; and office buildings [14]. Factors affecting the adoption of PV in the built environment have been presented in a number of studies [20–24]. However, there is little on BAPV in the multi-family tenant-owner cooperative housing sector. The purpose of this paper is to study how the organization of property management and the decision-making structure in tenant-owner cooperatives (TOCs) in Sweden facilitates or hampers the adoption of large-scale residential building applied photovoltaics (BAPV) by the executive boards in this housing sector. The focus is on the decision-making process and the challenges experienced by the potential adopters during the implementation phase.

The main research question is:

How do the organization of property management and the decision-making structure in the Swedish tenant-owner cooperative housing sector affect the adoption of large-scale residential BAPV by the TOCs?

This paper, which presents results based mainly on interviews in seven TOCs, is part of research at KTH—Royal Institute of Technology with the aim of determining the circumstances in which the installation of BAPV panels on existing apartment buildings can be an economically and technically viable energy source.

The case studies seek to find answers to the following research questions:

RQ1. What are the reasons behind the wish to and/or decision by executive boards in TOCs to install large-scale BAPV on the roofs of the buildings owned by the tenant-owner cooperative?

RQ2. How did the tenant-owner cooperatives that installed BAPV organize the work and what were the challenges they encountered as well as the solutions they used?

The structure of the paper is as follows: Section 2 presents a brief background on PV in Sweden and a description of the Swedish tenant-owner tenure, as well as agency related problems in the management of cooperative housing. Section 3 describes the literature on the adoption of sustainable innovations as well as the motives for and barriers to the adoption of energy efficiency measures. Section 4 presents the methods used to collect the data and to analyze it. Section 5 contains the results from the empirical analysis. Section 6 presents the discussion of the results as well as some concluding remarks. In this paper, large-scale residential BAPV denotes rooftop-mounted systems of at least 50 kWp installed in the multi-family housing sector.

2. Background

2.1. PV in Sweden

The multi-family sector accounts for only 8% of the number of building integrated photovoltaic (BIPV) and BAPV systems of at least 10 kWp installed in Sweden [25]. Large scale residential BAPV in the cooperative housing sector accounts for an even smaller percentage. Since 2007, the grid-connected PV capacity in Sweden, mainly in the form of BAPV, has rapidly expanded to four times that of the off-grid capacity. By 2013, an estimated total capacity of 43.2 MWp of PV was installed in Sweden, producing approximately 38 GWh. A majority of the systems are less than 5 years old [26]. Despite its location, the annual solar influx in the southern half of Sweden is comparable to that in Northern

Germany and there is an estimated PV electricity generation potential of 10–40 TWh/year from building-sited PV in the existing building stock [20,27]. Though the largest number of installations is probably in residential roof-mounted PV systems, as of 2013, grid connected commercial PV systems with a size of 20 kWp or larger had the largest market share with around 50% of the installed power [28]. The cost for complete turnkey PV systems in Sweden has fallen dramatically since 2005 as shown in Figure 1.

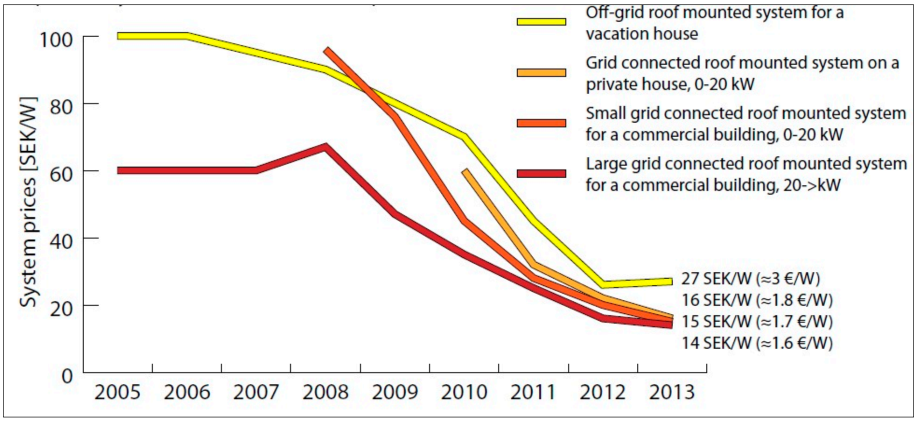

Figure 1. Typical prices for turnkey photovoltaic systems (excluding VAT) reported by Swedish installation companies [26].

Several key actors are involved in PV deployment in Sweden. These include the end-users who are mainly private homeowners, housing cooperatives, and organizations controlled by local authorities and farmers. Another group of significant actors is the turnkey entrepreneurs. These typically small companies are often also involved in the installation of other energy systems. Power companies (independent electricity retailers, groups of energy companies or grid operators) are increasingly taking the role of turnkey entrepreneurs. Architects and construction companies are another group of actors that are crucial to the integration of PV in the built environment. Advocacy organizations, such as the industry association Swedish Solar Energy (*Svensk Solenergi*) and the 14 regional energy agencies under the Swedish Energy Agency are active in disseminating information, and organize annual industrial and research seminars. Since 1995, the Swedish Energy Agency and the electricity companies have participated in the applied and user-oriented R&D program "Solar Power Programme" (*SolEl-programmet*), which provides an internet information portal, seminars and reports as well as several easy-to-use online planning tools that are helpful, for example, in calculating the electricity production and economy of envisioned PV systems. The Swedish Energy Agency awards an annual prize to a company or individual that has made the most outstanding contribution to the development and/or establishment of solar power in Sweden. The organization also publishes a list that contains a lot of the companies/firms/entities that have grid-connected PV systems in Sweden. Sweden has 21 administrative counties and the local authorities and urban planners also play a significant role in PV deployment [20].

Electricity costs are a sum of fixed costs and variable costs. The former include the trading fee and fixed grid charge. The latter comprise of the Nord Pool Spot price, the energy tax, the variable grid charge, VAT, the cost of green electricity certificate and an electricity surcharge. The economic feasibility of a residential BAPV installation depends on its location, initial costs, efficiency of the system, customer load, the expected future price of the bought as well as sold electricity, subsidies and incentives, taxation, interest rates and the expected consumption needs of the producer. Through substitution of bought electricity with self-production from the installed BAPV system, a tenant-owner cooperative can reduce the variable part of the expenditure on electricity costs. The investment can be analyzed using profitability indicators such as the net present value NPV, payback duration, or leveled cost of electricity (LCOE) [7,29–31].

Investment support for the installation of grid connected PV systems has existed in Sweden since 2005. For the period of 2013–2016, it amounts to SEK 210 million (approx. 24 million € using the exchange rate of 1€ = SEK 8.6 that was applicable in October 2012). The size of the installed system determines the amount of support received and the program is open to individual homeowners, commercial companies, and public entities alike. The Swedish investment subsidy scheme for PV systems has gone through several phases. During the initial period 2005–2008, it compensated for 70% of the investment cost. The level has gradually been lowered and during the period 2013–2016, it compensates for only 35% of the investment cost [20]. Since 2013, the maximum cost per kWp that is considered by the authorities to be an eligible cost (excluding VAT) is set at 37,000 SEK (4300 €). Solar power/heat hybrid systems are permitted to cost up to 90,000 SEK/kWp (10,000 €/kWp) plus VAT. The maximum subsidy per property is SEK 1,200,000 (approx. 140,000 €) [28]. The popularity of the scheme has overloaded the administrators with applications creating a one to two year waiting period for a decision. The Swedish PV market has been demand-constrained, with the investment subsidy largely determining the market size [20]. The discontinuations and subsequent resumptions in the subsidy program that have occurred in the past have discouraged actors such as installers from investing in equipment and the employment of permanent staff. The long and uncertain application process has also resulted in extra administrative costs and therefore, the program not only stimulates but also constitutes an upper cap on the Swedish PV market [26] (p. 15). Since 2009, only about one third of all of the applications for the support have been granted. By March 2014 the requests for support contained in the applications received, exceeded the money available for the period 2013–2016 [20,32].

Financial support for PV systems in Sweden consists of the investment support and the tax reduction that came into effect on 1 January 2015. Other forms of support are the tradable green electricity certificates (TGC) and certificates of origin. For private persons, the tradable electricity certificates are issued for a period of 15 years and are based on excess electricity fed into the grid. For other investors, such as TOCs, the certificates are based on all of the produced PV electricity. For each MWh approved, the producer is allotted a certificate that can be sold on a free market. However, there are problems in the market due to the lack of buyers of small quantities of certificates [20]. The average value of for a TGC in 2013 was 0.203 SEK/kWh (3.12 US¢/kWh) while certificates of origin had a value of 0.02 SEK/kWh (0.3 US¢/kWh) [7].

2.2. Tenant-Owner Cooperative Housing in Sweden

Housing cooperatives in Sweden are relatively small non-profit entities that typically own one housing estate or multi-dwelling building and their business is limited to providing housing services only [33]. However, many of the TOCs that were formed during the period 1961–1975 are large-sized with an average of about 300 to 500 dwellings due to the economies of scale in construction at the time.

By April 2014, there were 23,271 active housing cooperatives in Sweden [34]. A majority of these (57%) comprised of an average of 30 apartments. Only about 10% of the stock consisted of more than 100 dwellings (mainly in the "old housing" category). Though the TOCs might participate in collective social activities within their local area, they rarely do so and any sustainable environment activities that they carry out are focused on the cooperative and its members. The housing cooperatives are either initiated by, and are members of, one of the two national-wide organizations HSB (The Tenants' Savings and Building Societies) and Riksbyggen (The Cooperative Building Organization of the Swedish Trade Unions) or fall in the category of the "unattached" ones that are founded by building companies or through tenure conversion [35]. The cooperative owns the building and common areas with the members owning a share of the capital of the association. The tenant-owner, whose property right (*bostadsrätt*) is only the entitlement to reside in a specified dwelling, pays an annual fee for the management of the common areas and financial responsibilities of the cooperative. The characteristics of the dwelling determine the level of the fee. Whereas heating and hot water are normally included in the fee, the electricity consumed within the apartment is individually metered and paid for. The Swedish electricity market is deregulated and each tenant-owner is free to buy their supply on the open market. However, in order to help the members to save on grid charges, some cooperatives purchase the electricity centrally and then distribute it internally. There are also cooperatives in which all of the utilities are included in the fee. The collective billing of utilities in a cooperative has been shown to lead to wasteful behavior that lowers the gains due to energy efficiency measures [36]. The dwellings in this tenure form are not tradable but the right to abode (*bostadsrätt*) is exchangeable at market value and the price depends partly on the state of the building as well as the level of the annual fee being paid by the dweller. In this paper the term "apartment" is hereafter used as a synonym for *bostadsrätt*.

The TOC is managed through an executive board that is elected by the cooperative's members. The members of the board, who on average are elected for a period of two years, can be re-elected successively. There is no requirement that board members should have professional financial or legal experience and the board often consists of laypersons that are elected mainly because they are available to serve. Through their right to vote, using the principle of one member one ballot, the members of the TOC are entitled to take part in the decision-making on issues of a common interest. However, in practice, few members turn up at general meetings and most of the decisions are left in the hands of the board which has the liberty to choose the issues it wishes to put to a general vote. Whereas matters concerning the operation of the property are decided solely within the executive, the boards often seek approval of all of the members on decisions involving investments that might have a major effect on the size of the annual fee to be paid by each member. Thus, the decision to adopt BAPV will in some TOCs be taken by the board without having to seek the vote of the members or it might be put to a vote at a general meeting. An issue brought to the vote will be decided by majority vote among those present at a single meeting. However, decisions that affect the number of shares or those with far reaching consequences such as the decision to have one electricity meter for the whole cooperative are in most cases decided through voting during two consecutive general meetings. On the other hand, the decision to adopt individual metering, which reduces the communal economic responsibility will be left to the executive board to take without a vote as long as it is not too costly to install the meters. As service on the executive board of a TOC is voluntary and, on average, for a period of two years only, a lot of the work involved in operating the properties is outsourced to external service providers, such as Riksbyggen or HSB. The choice and quality of the activities that are carried out will to a large extent depend on the incentives of the decision-maker and/or the firm to which the work has been outsourced.

2.3. Agency Theory and Incentive Problems in the Cooperative Housing Sector

An agency relationship occurs when one or more persons (the principal(s)) engage another person (the agent) to perform some service on their behalf which involves delegating some decision making authority to the agent [37]. In a housing cooperative, this varies according to the character of an activity. Whereas a property company or contractor serves as an agent of the executive board, the board is an agent of the cooperative members. Due to the common ownership of property rights, the members in a cooperative might shirk from collective action as any positive effects are shared equally among all of the members. This leads to incentive problems that might be reflected in the management of the properties. Three of these incentive problems are investment-related: the common-property-problem; the horizon-problem and the portfolio-problem. Four incentive problems are decision-related: the monitoring problem; the follow-up problem; the influence cost problem and the decision-problem [38,39].

The common property incentive problem is due to the fact that there is a disparity between a member's contribution of equity or effort and the benefit from the contribution, which might lead to free rider tendencies since the equity is collectively owned. Common ownership might foster apathy among members leading to inefficiency and weak membership commitment [39]. The horizon problem is exemplified by the fact that benefits of an investment decision can only be captured during membership in the cooperative. Thus, there might be tendencies to back investment decisions with short payoff horizons. The consequence is that "*members are expected to become preoccupied with myopic perspectives on their cooperative membership*" [38] (p. 386). The fact that members have disparate time horizons, which affect their risk/reward profiles and consequently their views with respect to the cooperative's risk/reward profile might lead to what is known as the portfolio problem. Restricting rights to the residual claim to the collective body, for example in a situation where activities increase the value of the common properties but not the value of the apartment, means that individual members cannot use their shares to diversify their risk into other investments. Thus there might be a tendency to vote for activities with lower levels of risk. The investment decision will most likely be adapted to an "average" of member preferences which makes it optimal for only a fraction of the members, a choice that is economically inefficient [39].

The decision-related monitoring problem results from a situation where management, such as in a TOC, is passed on to specialists who are not the residual claimants. The agency costs to monitor the fact that the agent performs in the principal's interest might become quite steep in a situation where the cooperative is engaged in highly complex operations. The follow-up problem arises when the number of members is such that each member is unable to significantly influence the decision-making process or supervision of the management and can individually capture only a minimal share of potential benefits from such activities, thus, leaving the management to do as it pleases. On the other hand, the influence cost problem is due to the occurrence of groups of members in the cooperative who, if they have opposing interests, will carry out internal lobbying activities in order to sway the decision makers towards a particular action. The seventh of the incentive related problems within the governance of cooperatives is the decision-making problem. This comes about when the opinion among the members varies so much that it becomes difficult for the managers to decide how to weigh the different members' views whereby the ability to satisfy the members' interests is lost [39].

The Swedish housing market suffers from an enormous supply deficiency especially in the metropolitan regions, which has led to ever-increasing property prices. The expected value growth during the holding period serves as an incentive for purchasing the apartment and thereby becoming a member of the tenant-owner cooperative. A well-maintained building with low operative costs will lead to a higher return on the investment in the dwelling as the potential buyers take this into consideration when deciding on the price to pay [40]. TOCs have an incentive to invest in cost-reduction schemes, such as self-generated electricity for the common areas as this lowers the operative costs. Therefore, key drivers to decision-making in the TOCs with old buildings are among others, the building maintenance strategy and the maintenance plans adopted by the executive board in order to achieve a low level of annual fees. The executive board members, who have the duty to decide what is best for the cooperative in a long-term perspective, might also have individual incentives to prioritize short-term property management strategies that temporarily raise the value of their apartment.

3. Factors that Influence the Adoption of Small-Scale Renewable Electricity

3.1. Adoption of Innovations

The speed and degree to which an innovation spreads is attributed to (1) its relative advantage; (2) its compatibility with the pre-existing system; (3) its complexity; (4) its trialability; and (5) its observability [11]. Relative advantage indicates how beneficial the innovation is to an adopter in comparison to existing tools or procedures whereas complexity denotes the ease with which the innovation can be learned, and utilized. Trialability is the possibility to test (experiment on) the innovation for some time before deciding on adopting it (purchasing it), while observability refers to the degree to which the results of the innovation are visible to others, for example, the installation of a BAPV system. The rate of adoption will also depend on factors such as the number and authority of persons involved in making the innovation decision; the presence of communication channels e.g., media or interpersonal word of mouth; the extent of the promotion efforts applied by the change agent as well as the nature of the social system (e.g., its norms and interdependence). The decision-process consists of five stages: the knowledge stage, the persuasion stage, the decision stage, the implementation stage and the confirmation stage [11]. Dieperink *et al.* [12] provides a conceptual framework that explains the diffusion of energy-saving innovations in industry and the built environment. The core of the framework is the decision-making process of the potential adopter, which is influenced by the characteristics of the potential adopter (socio-economic and policy setting) and the networks in which he or she participates. The technological and economic characteristics of the innovation as well as more general contextual factors such as the market outlook within a certain sector, also impact on the process. The course taken to assess and decide on the adoption of an innovation is given as a procedure in four steps. For new technology to be considered at all, step 1 is that the firm needs *a serious occasion* that distracts it from its core business and routines [14]. Capacity problems due to unreliable performance; failure; dissatisfaction with the old system because of, for example, high operating costs; or the need to replace a depreciated installation are factors that will contribute to the consideration to adopt new technology.

Changes in regulations can lead to prohibition of the old technology thus increasing the willingness to adopt an innovation. Whether the firm actually considers the innovation options available will depend on the existence of a corporate energy and/or environmental policy as well as organizational provisions for their implementation [12,14,41]. Therefore, step 2 is a non-restrictive *initial perception* of how well the innovation meets certain firm-specific technical conditions and requirements. Step 3 is the *nature of decision-making* procedures, which are principally influenced by the firm's procedural culture and organization. These will determine the thoroughness of the assessment of the economic and technological aspects of the innovation. Step 4 consists of the observable assessment criteria applied and the values they are given. The firm's decision-making procedures are often presupposed to be of a rational-synoptic nature whereas in practice this is not the case. Various actors e.g., suppliers, installers, end-users, firms within the same sector and centers of expertise, disseminate information about the merits of the innovation or its shortcomings. Motivation, technical knowledge, experience and familiarity are critical factors that help to predict the conviction or interest that leads to persuasion [13]. A decision-maker will accept lower-quality information about an innovation that he is familiar with, than he or she needs before taking on unfamiliar items.

3.2. Motives for Adopting Energy Efficiency Measures

The motives for energy efficiency measures in the housing sector such as the installation of BAPV, depend on factors of an economic, social, or environmental character [16]. The decision to install a PV system on the roof of a house may depend on the wish by the homeowner to satisfy a number of needs that may relate to subsistence, belongingness, participation, home improvement, identity and the freedom of achieving relative independence from power companies [24]. A study of cooperative housing dwellers in Sweden found that households invest in small-scale electricity production due to concern for the environment; as a means of achieving self-sufficiency; as a protest against large-scale production, and because of the joy of producing one's own electricity [36]. In another study, investment in small-scale balcony-mounted PV panel was seen as a social act and a means of spreading the innovation to others [21] (p. 10). A positive experience with other sustainable environment investments has been shown to increase the potential for new ventures. Because the installation of solar heating systems and air heat pumps had progressed successfully, a housing association also adopted BAPV systems [5] (p. 796).

Endogenous factors such as technology awareness and desire for energy conservation, together with exogenous factors in the form of costs; regulatory and market structures as well as characteristics of the technology affect the rate of diffusion of household PV panels [22]. The influence and commitment of the local government to promoting energy efficient systems is another factor that affects the readiness to adopt energy efficiency measures [5,17,24]. Contextual factors that motivate the adoption of energy efficiency measures include the type of housing tenure, the age of the building as well as the energy cost level [12,18,42]. Characteristics such as the age and education level as well as income of the decision maker have been shown to have an effect on the propensity of homeowners to adopt energy efficiency measures. As the private income increases, the probability of adopting renewable energies in the home also increases and an increase in the electricity cost will lead to an increased willingness to adopt renewable energy sources [43]. Middle-aged and highly educated people are more willing to adopt renewable energy sources in their home, and individuals with a mean age of 55 years are more likely to undertake both investment and non-investment energy efficiency measures as opposed to younger ones [18]. Furthermore, high-income dwellers in multi-family housing have been found to be more likely to base their actions on environmental attitudes as compared to homeowners in detached houses who respond more to economic incentives [42]. Since the investment subsidy became available to private actors in Sweden, the typical user of PV systems is found to be one that is environmentally aware and interested in new technology and most end users can be characterized as early adopters [20] (p. 5).

Expectations have an effect on the decision-making, and positive emotion towards an activity is likely to lead to its adoption. However, in the presence of negative emotions such as mistrust concerning the professional advice; doubts about one's ability to manage the system; or a strong loss aversion, there is less likelihood of carrying out the activity [16]. Within tenant-owner cooperatives, the determinants of actions towards energy efficiency have been identified as consisting of *predisposing factors* (awareness, knowledge, norms, attitudes and the organization's perception of its own capacity to improve its energy efficiency); *enabling factors* (essentially of a contextual character e.g., the existence of expert advice, and subsidies) and *reinforcing factors* (e.g., feedback from external stakeholders). An example of a predisposing factor is the involvement of innovation champions who are persons that push for increased energy efficiency in the organization [36] (p. 70). Reliable leadership is an enabling factor, as a project group with a low membership turnover needs to be present throughout the project to advance continuity and keep initial innovative energy system ambitions on the project agenda [5] (p. 799). The complexity of the decision to adopt a PV system can be reduced through expert support at the decision-making stage as well as direct contact with others that have successfully installed a PV system [24].

3.3. Barriers to the Adoption of Energy Efficiency Measures

The literature on sustainability and renewable energy sources identifies a number of technical and non-technical barriers to the adoption of small-scale electricity production plants. The lack of information about available technology is another of the reasons for the slow adoption of micro-generation using renewable energy [22]. The large initial costs have been identified as one of the major obstacles to the adoption of solar energy [44]. Factors such as the potential adopters' lack of technical knowledge and difficulties due to limited trialability create barriers to the diffusion of PV systems. The approval of the municipal planning and construction authorities that is required for the mounting of a PV system involves an administrative procedure, which is a bureaucratic barrier to the adoption of PV [24]. Uncertainties in regard to building permits and tax rules, as well as the long and ambiguous application process for the investment support, have been shown to present hindrances to the adoption of PV in Sweden [20].

Distrust due to previous negative experiences has been shown to be an obstacle to the adoption of energy efficiency measures. Hoppe [5] (p. 796) notes that dissatisfaction with actions of the energy supplier in an earlier project led dwellers in a housing association to vote for the rejection of a project to install solar thermal system. In another housing association, ambitious energy efficiency plans were downgraded when the dwellers chose the installation of individual heating systems, despite evidence that preserving an existing system of collective heating after adopting innovative energy measures would have been beneficial to them. In this case, the decision by the dwellers was also urged by the housing association's fixed installation contractor, who feared a loss of income if renewable energy systems were to be installed, as it would reduce the need to install gas-fueled condensation boilers (the company's main business). Service providers, who stand to see a decrease in their business in case an innovative energy system is adopted, might not be willing to assist in promoting the diffusion of the innovation. Cost overruns due to energy efficiency measures during large-scale renovation projects deter from attempting to undertake financially risky plans again. New information about the maintenance status of a building can lead to changes in the investment analysis, with the consequence that the project gets postponed, downsized or rejected. In order to install a solar thermal system, a housing association discovered that it also had to change the energy infrastructure system (pipes) in the house, which would increase the costs. When the dwellers refused to agree to a rent increase the project was rejected.

A major problem when planning maintenance on buildings is the lack of information about the actual structure of the building as some construction activities might not have been properly documented. Economic efficiency calls for the need to have a plan for when to carry out various maintenance activities (e.g., changing the roof) and how to implement this plan. However, in a situation of uncertainty, there will be a higher degree of corrective maintenance, as well as opportunistic maintenance (carrying out some more maintenance measures than those originally intended) as long-term plans are liable to be continually changed [45]. The fact that members of the executive board in a TOC (the decision-makers) are laypersons that are elected for a short period of time or move from the cooperative, can create a barrier to the adoption of energy efficiency measures due to limited knowledge- and/or information management. In case the TOC does not have a proper record over the maintenance activities that have been carried out, it will be difficult to know what needs to be done. A maintenance plan that covers a number of years can serve as a useful tool that can help in planning for when to adopt energy efficiency measures. The order in which the activities are carried out will change according to the economic means available.

The terms and conditions of feeding surplus electricity into the grid affect the profitability of the investment and influence the willingness and interest in investing in electricity from renewable energy sources (RES-E). A Swedish government investigation published on 14 June 2013 rejected net metering as a means of promoting micro-produced RES-E in Sweden. Instead, a bill that provides a tax reduction of 0.60 SEK/kWh on electricity sold to the grid for fuses up to 100 A and for sales of up to 30,000 kWh per year came into effect on 1 January 2015 [46]. A micro-producer of renewable electricity in Sweden is one with a system and fuse that do not exceed 43.5 kWp and 63 A respectively [26]. A report from the Swedish Energy Agency shows that the investment support, described in 2.1 above, has outlived its purpose and that investments by tenant-owner cooperatives in BAPV can be profitable based on the tax discount that is available since 1 January 2015 [47,48].

4. Method

4.1. Empirical Study

The renovation of properties constructed during the period 1961–1975 is of major concern in Sweden. Therefore it was purposely decided to concentrate this study to properties from this period with a focus on the factors that affect the decision to install BAPV at the same time as the roof is being changed. This, in most cases takes places 30 to 50 years after construction. The study was carried out in two steps whereby in the first step the study focused on TOCs that wished to install BAPV and thereafter on the TOCs that had already installed BAPV. A study that seeks to determine the types of decisions made by members of the executive board and the factors that influence their decisions must take into account the characteristics of the TOC and more specifically the cooperative nature of the organization. The empirical analysis in this paper is based on a descriptive case study approach which is appropriate when "*the focus of the study is to answer* '*how*' *and* '*why*' *questions and you cannot manipulate the behaviour of those involved in the study*" [49] (p. 545).

This paper presents case reports of empirical studies in three TOCs that adopted BAPV. Earlier research had noted that a number of TOCs attached to Riksbyggen wished to install BAPV on the roofs of their building [9]. Through contact with the staff of Riksbyggen it was possible to come in touch with four TOCs that were willing to participate in the first part of this exploratory study. The buildings in these four TOCs were all constructed during the period 1961–1975. In the second part of the study two TOCs that had installed BAPV were identified through the website of Swedish Solar Energy. Inquiries through Riksbyggen produced one more TOC that had installed BAPV and was willing to participate in the study. These three TOCs are located in different regions and under the jurisdiction of three separate county governments. Two of the TOCs are attached to Riksbyggen and the third is attached to HSB.

Non-probability sampling (e.g., purposive sampling and convenience sampling), provides the researcher with the possibility to select a sample based on specific characteristics of a population that are of interest so as to answer a specified question [50–53]. Purposive sampling is suitable for qualitative studies where the researcher is interested in informants who have the best knowledge concerning the research topic [51]. In a TOC, the chairperson and the treasurer are in a good position to have information about the operation and maintenance strategies, plans for investments as well as the priorities of the cooperative. The property managers, who have the responsibility of carrying out the decisions of the executive board, are also an important source of information about the workings of the cooperative. The members of the cooperative, including those on the executive board, can have individual motives similar to those mentioned in 3.3.2 for wishing to see the adoption of BAPV in their TOC. However, decision-making is largely in the hands of the members of the executive board. These are assumed to be knowledgeable about the wishes of the cooperative's members through various forums such as the annual general meeting and other communication channels. Therefore, none of the dwellers was interviewed, as the focus was on the decision makers who are the "potential adopters" in the TOC. A major disadvantage with qualitative studies is that the results are context specific and do not aim to generalize the findings. Convenience sampling, which was also applied in this study, aggravates the problem, as it involves drawing samples that are both easily accessible and willing to participate in the research [53]. There is a possibility that the results obtained are from persons that are overly enthusiastic about the topic being reviewed or that only the projects that were successful are represented in the sample.

4.2. Data Collection

Data collection in a qualitative descriptive study is directed toward discovering the *who*, *what*, and *where* of events or experiences through collection techniques such as moderately structured individual and/or focus group interviews as well as observations of targeted events and the examination of documents [52]. The structured interview is the mode of choice when the interviewer knows what he or she does not know and can therefore frame appropriate questions to find it out [54]. A group interview provides the advantage that individuals build upon each other's responses, which can lead to rich data based upon group feedback. The main drawback of such "focus groups" is that one or two individuals in the group can anchor the thoughts of the rest, and individuals might guard their responses due to lack of confidentiality [55]. The primary data collection technique used was in form of seven semi-structured group interviews with the chairperson and the treasurer of the TOC together with the property manager in each of the seven TOCs in the study. The entrepreneur responsible for the installation of BAPV in one of the TOCs also took part in that particular meeting. The group interview was chosen because the participants had different roles and could complement each other.

The data were collected through questions that were based on an interview guide covering eight topics. The topics were: (1) background data about the executive board—used to cover questions such as how long the interviewees have been involved in the work of the executive board as well as the degree of technical and/or economic competence within the executive board; (2) maintenance planning—used to find out who draws the maintenance plans and how closely the plans are followed as well as who decides what is to be done and when; (3) the economic situation of the TOC—used to acquire an understanding of the TOC's economic and financial stability over a number of years; (4) energy-related measures—used to provide an overview of the energy-efficiency measures the TOC has carried out and which ones it has under consideration, who determines the measures that the TOC carries out as well as how different energy-efficiency measures are prioritized in the TOC; (5) adoption of BAPV—used to find out how the idea to adopt BAPV came up and how it ties in with the TOC's plans, who the persons involved in the project are as well as the factors that are considered to be in favor of or barriers to the adoption of BAPV in the TOC; (6) getting informed—used to find out the information that the executive board members needed to have before taking a decision on the adoption of BAPV; (7) implementation process – used to find out how the work was organized and carried out as well as the challenges that were experienced by the executive board during the implementation phase; (8) any other issues—used to cover any other subjects that the interviewees wanted to raise. The topics were based on factors that affect property management in the housing sector as well as the need to understand the reasons and the process taken by the executive board in adopting BAPV [12,56]. However, due to limited resources they were not tested for reliability, before being applied.

The same basic guide was used for all of the interviews with slight adjustments in the sequence of the topics where necessary. The questions asked were also refined during the study as more information was acquired, for example, about the challenges encountered in the installation of BAPV as well as other barriers to the adoption of large scale residential BAPV. The meetings took place between February and April 2013 in the office of the cooperative. Three of the meetings were carried out on the same day while, due to difficulties in finding a suitable date, the meeting with the fourth TOC took place six weeks after the first ones. The second part of the study took place about eight months later, between December 2013 and January 2014. The delay was due to a decision to wait for the results of the government investigation on net metering before continuing with step two of the study so that questions about the report, which was presented on the 14th June 2013, could be included in the interviews. A perfunctory inspection of the buildings in question was also carried out together with the interviewees after the meetings. On the 25 September 2014, the largest BAPV park in the multi-family residential sector in Sweden was inaugurated in Stockholm. It is owned by the city of Stockholm together with two of its daughter companies. It measures 10,000 m^2 on 40 buildings in the public rental housing sector and is estimated to generate 1.3 KWh [57]. More information about the challenges encountered in the installation of large-scale BAPV in the multi-family housing sector in Sweden was gained through contact with persons involved in the project.

4.3. Data Analysis

Qualitative research is generally characterized by the simultaneous collection and analysis of data whereby both jointly shape each other [49,52,58]. Qualitative analysis entails the tallying of responses and the number of responses in each response category. However, in a qualitative descriptive study, content analysis is not aimed at the presentation of frequencies but at the description of patterns or regularities in the data. There is no requirement to produce anything other than "*a descriptive summary of an occurrence, organized in a way that best contains the data collected and that will be most relevant to the audience for whom it is written*" [52] (p. 339). In order to maintain an informal atmosphere, an audio recording was not made of the interviews. Instead, the responses of the interviewees were documented in form of handwritten notes taken during the interview. Though the recording of interviews can have an effect on the participants' statements and should be limited as much as possible, taking notes as a mode of recording the interview has a weakness due to the fact that the documentation is not verbatim meaning that interpretation will depend on the ability of the researcher to recall as much as possible what has been said [59] (p. 295). Before ending the interview, the answers given were reviewed to find out if there were any questions or issues that needed to be clarified immediately by the interviewees. Whereas in step one of the study the focus had been principally on maintenance plans and adoption of BAPV, the analysis of the results during step two of the study concentrated on understanding the strategy chosen by the TOC in its adoption of BAPV and the experiences of the participants involved in the implementation process. In order to cross-check the verbal information received during the interview, documents of the TOC, such as financial reports, maintenance plans, contracts with utility companies and reports indicating the electricity generated by the installed BAPV systems were analyzed after the interview. The data obtained through the interview transcripts and other text documents from each TOC was put together into a case report. The transcripts from all of the interviews were also analyzed in order to identify issues that were common in the answers presented from different TOCs. However, this was not based on rigorous coding as required in content analysis [54], or thematic analysis [60], but rather on the comprehension of how the respondents had answered a particular question. As the issues identified were closely linked to the questions asked they cannot be taken as themes on their own but they provide the basis for analyzing the results on factors that affect the decision-making about the adoption of BAPV in the TOCs.

5. Results

This section starts with a general description of all of the TOCs in the study followed by a descriptive presentation of the results of the interviews from the four TOCs in the first step of the study. The results from the three TOCs in the second step of the study are thereafter presented in form of case reports.

5.1. Brief Description of the Seven Cooperatives in the Study

Responses to questions under topics 1 to 3 in the interview guide revealed that there was an average of five persons on the executive board in the examined tenant-owner cooperatives with a majority being men over 50 years except in two of the seven cases. Deputies participated in most of the board meetings and contributed ideas but their right to vote was restricted. A review of text documents as well as responses to questions on the economic stability of the TOC indicated that the gender of the persons who had a majority on the executive board appeared to have had some effect on the maintenance, as well as sustainable environment activities that had been prioritized in the TOC. Persons that have served on the executive board over several mandate periods can be a good source of information about the reasons for activities carried out in the past and six out of the seven executive boards had at least one ordinary member that had been on the board for more than seven years. Five out of the seven cooperatives had members on the executive board with a high degree of technical know-how though this was not in the field of BAPV systems. Three of the executive boards had members whose employment was or had been in the financial sector and therefore can be considered to be more financially competent than the average board member. All of the seven cooperatives had outsourced their accounting as well as technical property management. However, financial management was kept in-house as a responsibility of the treasurer.

All of the studied cooperatives had both short-term (1–3 years), as well as long-term (4–25 years) maintenance plans that they strived to follow. The external property managers drafted the plans, which the executive board analyzed and revised when necessary. Maintenance priorities often followed the long-term plans but had in some cases shifted according to the composition of the executive board or due to factors of an acute nature beyond the board's control. The economic status of the tenant-owner cooperatives in the study appeared to be satisfactory though it varied broadly within the seven cases. There was collective purchase of household electricity in two of the cooperatives. One of these had individual metering for the household electricity while in the second one, the cost of the electricity consumed within the dwelling was included in the annual fee paid to the cooperative. Five of the studied cooperatives appeared to have electricity costs per square meter of dwelling space (Table 1) that were much higher than the annual average of €2.17/m^2 of total dwelling space for a multi-family building constructed or refurbished during the period 1960–1990 [61]. It is assumed that a very large difference between this average and what the TOC pays would prompt the executive board to carry out measures to lower the electricity costs. The reported costs in two of the TOCs were not comparable as they included household electricity.

Table 1. Some features of the studied tenant-owner cooperatives.

TOC	Dwellings	Year of Construction	Size of board	Men on board [1]	Average age	BAPV installed	Electricity cost [2] (2013)
TOC 1	301	1971	5	33% (40)	53	-	-
TOC 2	376	1961	5	56% (80)	48	-	9.55
TOC 3	506	1968	5	78% (80)	56	-	13.90
TOC 4	651	1962	7	58% (71)	55	-	13.46

Table 1. *Cont.*

TOC	Dwellings	Year of Construction	Size of board	Men on board [1]	Average age	BAPV installed	Electricity cost [2] (2013)
TOC 5	16	1992	6	33% (33)	44	50 kWp	-
TOC 6	60	1947	5	50% (60)	41	140 kWp	12.59
TOC 7	546	1966	7	57% (57)	55	627 kWp	16.94 [1]

Note: [1] % in brackets represents the whole board including the deputies; [2] the level of the electricity bill paid by the tenant-owner cooperative in 2013 in €/m^2 of total dwelling space in the TOC. It is used here as a rough indicator of the gap to the average of €2.17/m^2 in buildings from the same construction period.

5.2. Results from Step 1 of the Study—TOCs that Had Not Yet Installed BAPV

An analysis of the responses as well as text documents during step 1 of the study revealed that all of the four TOCs had carried out various energy-saving measures such as installing district heating and the use of low-energy bulbs in the common areas. However, two of the TOCs were considering switching to some other heating energy source. This was due to the fact that the energy prices for district heating had risen much faster than what had been anticipated at the time the decision to use this energy source was taken. This was also a cause of concern when considering the adoption of BAPV, as there was uncertainty about how profitable the investment would be, given the experience with the district heating. Though all of the cooperatives were considering installing BAPV on the roofs of their buildings only two of them had not yet renovated their roofs, and could think of combining the installation and the renovation activities.

According to responses from these four TOCs, the wish to adopt BAPV was due to the fact that it was seen as a way of reducing the TOC's operation costs, as well as a means of contributing towards a sustainable environment. Another motive given by a cooperative that had very good economy and with an executive board that had served together for a long time was that: "*We are looking for thrilling projects to undertake in order to promote the image of the cooperative*".

The status of the maintenance of the buildings in all of the cooperatives appeared to be satisfactory and followed a long-term plan except in one TOC in which the operation and maintenance strategy as well as priorities chosen over a number of years did not reflect the poor economic status of this cooperative. The reason behind the wish to install BAPV in that TOC which was: "*we want to be the TOC in our area with the lowest annual fee for the members*", appears to be in the same spirit.

During the interviews one TOC expressed a strong commitment to go ahead as soon as possible with the process to adopt BAPV. This TOC also appeared to have come very far in their decision-making process according to the framework presented in Dieperink *et al.* [12]. A second TOC answered that they could go ahead and install BAPV as soon as possible. However, an analysis of their text documents revealed that the economic status of this cooperative was not very good. Another TOC could be interested in installing BAPV in case they got more information especially about the profitability of the investment. This cooperative had good economy and an executive board comprising of members who felt dynamic and not afraid of "innovative" ways to lower operation costs. However, costly and time-consuming maintenance works had turned the voluntary work of the executive board into something that resembled full time employment, which hindered plans for any new projects. Responses from the fourth TOC indicated a positive inclination towards installing BAPV but movements in the ground under the buildings had led to acute maintenance needs and the decision to postpone investments in other activities. At the time of the meetings, the effect of restrictions on imports of solar panels made in China was of concern, as this affected the investment calculations. Even though the focus of the interviews was on BAPV, the underlying concern of the executive members was on energy costs in general and they considered the adoption of BAPV in comparison to or as a complement to other energy sources. There was concern about how long the investment support for BAPV installations would last, as synchronizing the installation with other maintenance activities could provide economies of scale. There was also hope that the government would allow net metering which, at that time, was still under investigation. Members of the executive boards appeared not to be so knowledgeable about technical issues concerning BAPV and their worries focused mainly on issues that affected the cooperative's economic status, which they found easier to understand.

In summary, the results of this part of the study indicate that the TOCs wished to adopt BAPV because of a need to lower operating costs; in order to achieve cost efficiency in the installation process in case the BAPV system was put up at the same time as the roof was being renovated; as a means of contributing towards a sustainable environment and as a way to promote the image of the cooperative. The cooperatives had already carried out various energy-efficiency measures and the installation of BAPV appeared to be in line with general strategies towards environment friendly property management.

5.3. Experiences from the Tenant-Owner Cooperatives that Have Installed BAPV

5.3.1. Case Report 1

The first interview during step 2 of the study was with a TOC in which the executive board had a long-term strategy to reduce energy costs and place the cooperative's economic status on more solid ground. They had approved a plan to install solar thermal and informed their district heating company about the changes they intended to make. However, due to clauses in the contract with the utility company, a reduction in the demand for district heating would not have led to lower costs. Therefore, the members of the executive chose to switch to BAPV instead. The size of the system was based on the roof space available. Contributing towards a sustainable environment was not one of the factors considered before the decision was taken to adopt BAPV. Two of the members on the executive board who are engineers by profession were strongly involved in the project and acted as "champions of the cause" as mentioned in the literature [36] (p. 70). They lay behind most of the decisions taken in the executive board. The executive board chose to utilize a turnkey contract and outsourced the implementation process to a local firm. According to the board members, the principal-agent relationship with the contractor "*proceeded well and with a very high degree of trust between the partners*". From the responses, there is an indication that the board is doubtful whether a project manager from the nationwide organization to which this TOC is attached would have worked as well in this particular case. The fact that the entrepreneur was from the area and had many local contacts was found to be of importance in a number of situations.

The installation of the BAPV system was delayed by a number of challenges. The first one was that the municipality lacked routines for handling building permits for large-scale residential BAPV. The municipal architect refused to authorize the planned installation as the black BAPV panels would contrast too much with the red tiles on the roof. In order to overcome this obstacle, the members of the executive board advanced the changing of the roof tiles by five years, which increased the installation cost for the BAPV system by 25%. The second challenge was that according to the requirements for receiving the investment support, the installation had to be completed within the calendar year in which the application had been made. Because of the delay in receiving the building permit, the implementation process (procurement and installation) took longer than planned. Therefore, in order to start and complete the BAPV project within the duration of the subsidy, the executive board decided to skip the bidding process as a way of choosing the contractor. Unknown at the time was the fact that the government would later extend the period of the support by another three years, from December 2013 to December 2016. They estimate that bidding could have lowered the cost of the project by about 25% to 33%. Another consequence of the delay was that by the time the cooperative's application for investment support was approved, the subsidy had been lowered from a level that reimbursed 45% of the total cost to a level that covered 35% of the total cost. Another of the challenges experienced by the TOC was in form of difficulties in acquiring the correct information from members of staff of the utility company with regard to the requirements for a grid connection. A consultant was hired to help the cooperative in this matter before the BAPV system was commissioned.

At the time of the meeting, the system had been functional for a number of months but the executive board had never carried out any investment analysis for BAPV. However, they had carried out one for the initially intended solar thermal project. According to the contractor, the BAPV system had a 10-year payback period. The fact that electricity prices had fallen and that the project costs had increased more than expected had not led the executive board to revise the expected payback period. Through the help of the contractor, the cooperative has acquired the various financial incentives available such as green electricity certificates and guarantees of origin. On commissioning the BAPV installation, the utility company categorized it as one small commercial system. The executive board has plans to register each building as a separate micro-producing residential BAPV system, as this would provide the TOC with more generous tariffs.

In summary, it can be noted that the main reason why the executive board in this TOC chose to adopt BAPV was to reduce operating costs, even though BAPV was not the initially intended energy-efficiency measure. To a great extent, the decision was in line with the property management priorities of the TOC. The installation work was outsourced to a turnkey entrepreneur that was chosen without any bidding process and the main challenges encountered during the implementation process were mainly due to lack of information about what is required by various actors, such as the utility company and the municipal authorities. The TOC overcame the barriers to the adoption of BAPV through the help of external advisors and the fact that there were persons on the executive board who were used to managing projects of a technical nature.

5.3.2. Case 2

This cooperative had a long-term maintenance plan in which the roof was to be changed as well as the electric wiring in all of the buildings. Three persons were delegated by the executive board to look into the most cost-efficient way of doing this. This subcommittee proposed the idea to install BAPV, based on the argument that the scaffolding for the roof renovation would already be in place, which would lower the cost of adopting BAPV. The members of the executive accepted the recommended measure and agreed upon how much the TOC would invest in the project. Two other reasons that weighed in favor of the decision to adopt BAPV were the wish to reduce the TOC's operating costs as well as to make a contribution to a sustainable environment through lowering carbon dioxide emissions. Without requesting for bids from prospective contractors, the executive board awarded the contract to manage the projection and procurement of the BAPV system to a local firm that had installed rooftop BAPV on the office building of a company with ties to the cooperative movement. A member of the executive board, who is also the national organization's representative, took on the role of building project manager for the BAPV installation.

The analysis of text documents revealed that the executive board in this TOC depends heavily on help from the attached national organization for technical guidance and during the interview it emerged that the idea to install BAPV had originated from the local office of the national organization. Procurement of the BAPV system took place one building at a time and was based on a fixed price per W. The equity sum that the executive board chose to invest in the project determined the size of the installed BAPV system. A decision was also taken that any subsidy, such as the investment support, was to be used to purchase more BAPV panels. The first solar panels were commissioned within a few months after the decision to adopt had been taken. According to the executive members, the fact that the subcontractors were also local firms was quite advantageous in getting the work done without major delays. The treasurer of the TOC was of the opinion that the choice by the executive board to use cost-reimbursable contracts instead of fixed-price contracts during the project helped the cooperative to hold the costs down. The installation of the BAPV system preceded the changing of the electric system, which was the activity originally planned for.

As large-scale BAPV installations in the municipality had previously only been on office or public service buildings, there was a lack of routines governing the process required in order to receive a building permit for large-scale residential BAPV. The members of the executive board became pioneers who worked hand in hand with municipal council staff in order to formulate, as well as fulfill, the necessary requirements. The board had an experienced contractor in charge of the project and members of the executive board who were knowledgeable and therefore, according to the respondents, most of the challenges encountered were beyond the control of the executive. One of the factors that the board members had taken into account before deciding to adopt BAPV, was that they would be able to utilize net metering in order to increase the profitability of the project. The members of the executive were disappointed that the government investigation on this issue had recommended another form of subsidy but they were hopeful that the government would still go ahead and permit net metering. Another measure taken by the executive board as a way of lowering the dwelling costs of the members in the cooperative was to see to it that the members voted for a change in the statutes to the effect that the cooperative became the sole purchaser of electricity for the dwellers. This measure, which had not come into effect by the time the interview took place, was intended to lower the fixed costs for the households who will still have individual metering but without each family having to pay the grid charge. According to the respondents, the adoption of BAPV has been a successful enterprise as the installation has generated nationwide publicity for the TOC. Despite the lack of a poll, they believe that the members of the cooperative are happy with the project.

At the time of the meeting, the various installations had been functional for about a year. Before starting the project, the board was provided with an investment analysis by the contractor. It showed that the project would be profitable even without the investment support. The analysis estimated an internal rate of return between 5% and 13% and a payback period of 8–13 years for the project depending on the support received. The investment support was 45% of the costs during the first year and 35% for the installations that followed. The executive board calculates on substantially lowering the operating costs but, as several of the parameters from the original investment analysis had changed since the start of the project, the respondents expressed an interest in getting a new and more detailed profitability analysis of the project.

In summary, it can be noted that the main reason for adopting BAPV was not due to a serious occasion that compelled the cooperative to adapt its energy consumption but an opportunistic action due to the need to utilize the scaffolding that had been put up in order to renovate the roof. The decision followed in the wake of maintenance measures that had been planned (reroofing and rewiring). However, the adoption of BAPV took place before one of the originally intended activities and the installation work was outsourced to a turnkey entrepreneur that was chosen without any bidding process. The main challenges encountered during the implementation process are related to the uncertainty about the conditions and policies governing the micro-production of renewable energy. The lack of major hindrances during the installation process was in part due to the help of external advisors.

5.3.3. Case 3

This cooperative planned to replace the worn-out electric heaters in each apartment with a more energy-efficient heating system and had analyzed several alternatives such as district heating and geothermal heat pumps. Due to special characteristics of the cooperative and its buildings, the most optimal solution was found to be the installation of an exhaust air heat pump system. As part of a long-term strategy, the executive board decided to install BAPV too, as this would further reduce the operation costs of the TOC and contribute to a sustainable environment. With the new installations, the heating cost would switch from individual to collective billing, and the electricity costs for the common areas would decrease. Members of the executive board hoped that the lower costs would contribute to a fall in the turnover rate of the dwellers at the same time as it would raise the value of the apartments. The BAPV system lies on top of the existing roof, which according to the maintenance plans of the cooperative is due to be changed in about six years' time. In order to carry out the installation, the executive board took in bids for a turnkey contract after which they chose a small company from the region. The board relied heavily on assistance from its national organization in carrying out this selection. According to the interviewees, the members of the executive were satisfied with the contractor, with whom the cooperative had not had any previous relations. In its efforts to promote a sustainable environment, the executive board included a condition in the procurement specification, which required the contractor to use only solar panels manufactured in an environment friendly and ethical manner. The solar panels used are of German origin.

According to the interviewees, the executive board in this TOC experienced few challenges during the implementation process. The TOC is located close to the City hall in a small region where it is easy to meet spontaneously and the cooperative did not have any problems in getting the building permit.

The greatest challenge reported was that over twenty-five firms put in bids for the installation contract. The consequence was that the shortlisting process had taken longer than what the members of the board had counted on. After adopting BAPV, the TOCs switched its electricity-trading partner to a company that offered incentives to tenant-owner cooperatives. However, the executive board signed a separate contract with another company that purchases the surplus electricity produced by the BAPV system. These changes went smoothly.

The executive board used the payback method in its investment analysis, which indicated a profitable return from the exhaust air heat pump, as well as the BAPV systems. Both are 100% debt-financed. However, the duration of the payback period was not the main factor behind in the decision to adopt BAPV. According to the chairperson: "*a tenant-owner cooperative is a long term property owner and can afford to have an investment analysis based on a longer duration than that for a private owner*". The installation of the BAPV system led to another positive development in this tenant-owner cooperative. The long process that included a number of other maintenance activities necessitated regular meetings to provide the members with reports about the progress of the projects. This increased the sense of belonging and brought the dwellers socially closer together. The turnover rate decreased considerably and the members of the cooperative participate more in collective activities.

In summary, it can be noted that the main reason for adopting BAPV was due to the fact that the executive felt compelled to replace another depreciated installation. The decision was in that sense, in line with the property management priorities of the TOC. The installation work was outsourced to a turnkey entrepreneur that was chosen through a bidding process and the main challenges encountered were mainly due to the time the procurement process took.

6. Discussion and Concluding Remarks

In the literature, the adoption of energy-saving innovations has been shown to follow a given pattern that involves the occurrence of a serious situation that leads to the need for the innovation, acquiring information about the innovation, taking decisions about the innovation, implementing the decisions and evaluating the results [11,12]. The results of this study indicate that the main reason behind the desire and choice to install BAPV in the tenant-owner co-operative sector is the wish to lower operating costs. Most of the TOCs have electricity cost levels that lie high above the average for comparable properties and a need to make changes related to their demand for bought electricity. However, this is not always a priority in the maintenance plans. The decision to adopt BAPV appears to be based mainly on the opportunity to utilize it as a means of achieving some other goals, such as the promotion of the TOC and as a complement to an existing energy source, other than the replacement of an inefficient energy source. Due to lack of technical competence within the executive boards, the work to install the BAPV is outsourced to turnkey entrepreneurs.

A rational decision-making process is expected to lie behind the adoption of sustainable innovations by organizations and the existence of a corporate energy and/or environmental policy, as well as organizational provision for the implementation influences the decision [12]. The results reveal that the reliability and technical fit of BAPV does not appear to be of concern and the TOCs that had decided to install BAPV (the adopters) were already past the implementation stage by the time the interviews were carried out. On the other hand, there appears to be a lack of detailed investment analysis of the profitability of the activity. Members of the executive boards in the three TOCs that have installed BAPV are contented with the measure as they can point to payback periods that are much shorter than the economic lifetime of the installed systems. However, in the absence of a serious occasion that highlights the need for the innovation, it can be logical to assume that the decision to adopt BAPV would not have taken place unless it was based on some other criteria. An approach based exclusively on economic reasoning does not provide sufficient grounds on which to adequately explain the behavior of the (potentially) adopting actors [12]. The argument in the following section is that the decisions observed are rational but that they are the result of hidden incentives rather than strenuous efforts to achieve optimum economic gains for the tenant-owner cooperative. The agency theory, which provides a base for analyzing actions taken by different persons in a situation where a part of the execution is in the hands of an agent, is used to explain this standpoint.

6.1. Adoption and Installation of BAPV in View of Agency Related Problems

6.1.1. The Horizon Incentive Problem

The horizon incentive problem can be used to explain why actions with short-term returns (payback period) will tend to be prioritized over other activities [39]. Even when factors, such as the price of the solar panels, seemed to become uncertain or the cost of the installation increased by 25% as in case report 1, the decision to install BAPV was itself seen as a success by the executive board members involved. Sweden ranks well as a society that is highly aware of the consequences of climate change and what to do to counter the negative trend [62]. An installed BAPV system is a visual sign that the cooperative and its members are active in the campaign towards a sustainable environment. Where it exists, reference to the BAPV and/or PV thermal installation often appears in adverts of apartments for sale. According to the interviews, the decision makers and the members of the cooperatives see the investment in PV as a measure with positive socio-economic effects and for the environment. However, there is currently no evidence of an economic character to support the arguments used by executive members to highlight the merits of the PV project, such as a short payback period and that the activity was "*good for the cooperative*". Thus, the notion that the decision to install the BAPV system is in part due to existence of the horizon incentive problem cannot be discarded.

6.1.2. The Influence Problem

The composition of the board in a tenant-owner cooperative lays the ground for the interests at play, which has a direct effect on the adoption or not of PV. By means of internal lobbying activities, a group of people or an individual can sway the decision makers towards a particular action that might not always be to the advantage of the cooperative. Being of middle age with a high education level as well as high-income level appears to raise the probability that an energy-efficiency activity will take place [43]. Fifty-five percent of the inhabitants in tenant-owner cooperatives are women, 66 percent of the members of the executive boards and 80 percent of the chairpersons are men [63]. Only two of the seven studied cooperatives had a majority of women on the executive board. Though the effect of a decision maker's gender has not been studied as a factor in the adoption of sustainable innovations such as BAPV, the presence of champions for the cause have, on the other hand, been shown to have a major influence on the probability that an executive board accepts to adopt an innovative energy-efficiency measure [18,36,64]. This was clearly the situation in one of the cases studied whereby even when the project appeared to become overly costly it was not stopped.

6.1.3. Information Asymmetry and Principal-Agent Problems

Members of the executive are non-professionals who rely largely on external advice and competence. Selecting the right advisers within property management is crucial in order to have activities that correspond to the needs of the cooperative. The market for large scale residential BAPV in Sweden is still in its infancy but growing, and attracting many new suppliers and installers [26]. Information asymmetry refers to the situation in which one actor has access to information that is not known to the opposite party, such as the quality of performance. There are expenses related to monitoring the contractor/agent especially in a situation where the executive board lacks procurement proficiency or the necessary competence to supervise the process. Past relationships or recommendations provide important information about a contractor and in two out of the three cases studied, a local entrepreneur was contracted without a bidding process, to install the BAPV system. The need to minimize principal-agency problems can have a major influence on how the work is organized, the type of contract chosen, as well as the project manager/installer contracted. On the other hand, as noted through cases 1 and 3, a properly conducted and well-defined bidding specification can shorten the procurement process and lead to a reduction in the costs of the project. Moral hazard on the part of the executive members or the contracted property manager is another problem related to the principal-agent relationship which can lead to neglected maintenance on one hand and a push for expensive but visual investment projects on the other hand, as in the case of the TOC with poor economy that wished to install BAPV.

The adoption of large scale residential BAPV can be improved through the sharing of information between the concerned parties. The lack of a standardized procedure for the approval of BAPV building permits by county and municipal authorities leads to delays. The results of the interviews indicate that nearness to government officials facilitates communication. However, not all cooperatives can locate next to the city hall. There is an urgent need for local governments to address this problem as a means of further encouraging BAPV in the multi-family housing sector. The greatest challenge encountered by the public housing companies of Stockholm Municipality in their installation of the 10,000 m^2 rooftop BAPV park was the lack of routines governing the process to acquire the required building permit. Challenges to the adoption of BAPV due to principal-agency problems also become apparent when utility companies utilize a complicated tariff system to thwart activities that would lead to energy-efficiency as described in case report 1.

6.2. Concluding Remarks

The unique character of this tenure form makes it possible to take decisions that fall between the profit-maximizing choices made by a corporate housing company and the small-scale energy-efficiency measures of a single homeowner. The non-investment motives and incentives, as well as barriers, to the adoption of BAPV in this housing sector are in many ways similar to those of single-family dwellers. The main difference lies in the nature of ownership and organization form of the decision-making in the tenant-owner cooperatives. The model on the adoption of innovations [11], together with the framework for the adoption of sustainable innovations by organizations [12] provide tools that are helpful in understanding the decision-making process behind innovative measures such as the installation of BAPV. However, decision-making in TOCs is in the hands of amateurs who rely heavily on advisory services provided by external professionals. The results of this study indicate that the reasons behind the choice to adopt BAPV and how the process to install large-scale BAPV is organized by the executive boards appear to be rational but suboptimal and inefficient, as the decisions seem to be affected by actions to minimize principal-agency problems such as the choice to award contracts to local actors. HSB and Riskbyggen are among the largest property managers for both the attached as well as some independent cooperatives with close to 75% of the market. However, they lack coordinated efforts to promote BAPV in the existing stock and are not the given source of advice for the executive board.

The average term of service on the executive board is two years and often "champions of the cause" are the drivers of efforts towards the promotion of energy efficiency measures [18,36]. Challenges due to moral hazard problems, information asymmetry, investment risk, and the voluntary nature of the work on the executive board affect the adoption of large-scale residential BAPV by the TOCs. There is a need to strengthen the quality and management of knowledge as well as procurement proficiency in this sector. This will enable the executive boards of the tenant-owner cooperatives to take better and more informed decisions in order to harness the potential presented by the many properties in need of refurbishment and with roof space suitable for BAPV. This study is based on a very limited number of TCOs that participated voluntarily. It is possible that a different set of TCOs especially within non-adopters would have presented a number of challenges that have not been revealed here. Since the interviews were carried out, a new law providing a tax reduction for micro-production of electricity has come into effect. A study of how this change affects the desire to adopt large-scale BAPV by TCOs that have not considered it before can provide some valuable knowledge on the various ways to promote renewable energy sources in this sector.

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Conflicts of Interest

The author declares no conflict of interest.

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