LESSONS IN COMMUNITY OWNED PV FROM SWEDISH MULTI-FAMILY HOUSING COOPERATIVES

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ABSTRACT: With increasing population shifts to urban areas and demands for post-war energy efficient renovations across Europe, solar photovoltaic (PV) deployment in multi-family housing will play an increasingly important role towards meeting renewable energy, climate, and sustainability goals. This paper describes the stories of three Swedish residential cooperatives who have installed large-scale PV systems across multiple buildings on their estates. In all cases, reduced operating costs were the original primary motivator; however unforeseen cost increases, changes in policy, and excess supply in the electricity market have made economic success less likely than originally expected. Regardless, the owners consider their projects a success due in part to short term social and long-term environmental benefits, which were originally less important and difficult to quantify. We can conclude that community owned PV offers more than just economic benefits, and Sweden's unique ownership and management structure of residential cooperatives can offer insights towards increased deployment in other nations in Europe.
Keywords: PV system, economic analysis, sociological, case study

1 INTRODUCTION

With increasing population shifts to urban areas and demands for post-war energy efficient renovations across Europe, solar photovoltaic (PV) deployment in multi-family housing will play an increasingly important role towards meeting ambitious renewable energy, climate and sustainability goals. While there are many technical and economic opportunities for community owned PV, the social and legal challenges of coordinating many owners can hinder development. Therefore identifying successful pathways is critically important towards gaining access to PV ownership for this increasingly large portion of society. It is not often that Sweden is considered a pioneer in solar PV installation; however the unique ownership and management structure of tenant-owned, multi-family housing (cooperatives) can offer lessons on increased deployment of community scale PV.

1.1 Objective and approach

In the interest of building the knowledge pool of community owned solar projects, this paper tells the stories of three Swedish housing cooperatives who have installed 56 kW_p, 115 kW_p, and 627 kW_p systems across multiple buildings on their respective estates. Semi-structured interviews of the executive boards and property managers have been conducted to collect qualitative experiences, and have been supported by quantitative data found in annual reports, maintenance plans, and technical and financial information regarding the PV installation. A techno-economic analysis of each system is made by the authors, and where available will be compared with the expectations the board had during the planning phase. The results are presented as case studies describing each cooperative's experience, followed by a discussion and conclusions.

1.2 Background on Swedish cooperative housing

Swedish housing cooperatives, which make up 22% of all residences in Sweden, are non-profit associations that typically own one housing estate or multi-family dwelling [1]. They are owned exclusively by the residents of the estate, who are then given the right to reside in a portion of the building (e.g. apartment) and pay an annual fee for the operational and financial management of the association. A well maintained building with low operations costs will lead to a higher return for the owners of the cooperative, meaning cooperatives have an incentive to invest in cost-reduction schemes, such as self-generated electricity, in order to reduce utility fees and boost market value.

An executive board elected from the members for a period of two years acts as a governing agent for the cooperative. Each member is given a single vote during the annual meeting, but it is exercised only on issues the board deems necessary to call a general vote for. Typically, investment decisions which might have a significant effect on the annual fee paid by each member, such as major energy installations, are brought to a general vote.

Electricity use in cooperatives can be split into two categories; communal and private. Communal electricity includes stairwell and exterior lighting, HVAC, and laundry rooms, while private electricity is that which is used in individual apartments. Typically, the cooperative purchases communal electricity and the costs are distributed in the annual fee. Apartments usually have their own meters and purchase electricity from the retailer of their choice, but it is also possible for apartments to be included in the communal fee particularly if there is direct electric heating. Another structure is for the cooperative to have a single meter with the utility and for apartments to be metered and billed internally by the cooperative.

1.3 Background on Swedish electricity market

Swedish electricity supply is dominated by two sources; hydro and nuclear power, which make up 90% of the supply, with the remaining 10% being primarily biomass fueled co-generation [2]. The annual demand is approximately 145 TWh, or 15.3 MWh per capita, and peaks during the winter months due to a high use of electric heating. Sweden has high voltage links between

Norway, Finland, Denmark, Germany, and Poland, and is typically a net exporter of electricity.

The wholesale and retail electricity markets are both deregulated. The majority of electricity is traded in the Nord Pool Spot wholesale market, where hourly prices are set one day-ahead. Retailers purchase electricity from Nord Pool and resell it to end consumers, who are free to choose any retailer. They can also choose the frequency to which their tariffs follow the market, from several years to hourly. The most popular and fastest growing contract type is variable price adjusted monthly [3].

After Sweden joined Nord Pool in 1996, average spot prices fell by 50% and stayed consistently low for 4 years. During the 2000's prices became more volatile and began to trend upwards, and had quadrupled by the end of the decade. Since 2013, there has been relatively low demand (driven primarily by mild winters and reduced industrial output) and considerable oversupply (most reactors are online and precipitation has been high) such that prices are now back to the same level as 2001 [2]. This, combined with unfavorable government policy, has caused two large utilities, Vattenfall and E.On to announce early retirement of four of their oldest reactors [4] (p.152-154). The future for the Swedish electricity market is extremely uncertain, largely hinging on the question; will nuclear power continue? And if not, what will replace it?

To support renewable energy development, Sweden has a green certificate market open to a wide variety of renewable energy sources. Demand for certificates is set by the government, and free moving prices signal potential suppliers to build. One certificate is earned for each MWh generated, and a facility is able to earn and sell its certificates for a maximum of 15 years. The green certificate program has been mostly utilized by wind and biomass based CHP [2].

1.4 Background on Swedish solar PV market

Relative to many other countries in Europe, the Swedish market for solar power is small. In 2014, 36.2 MW were installed for a cumulative total of nearly 80 MW [5]. As shown in Figure 1, the market has been growing rapidly in recent years. This is correlated with the rapid drop in costs, shown in Figure 2, which are currently 1.3–1.6[1] €/W_p (excluding VAT) for a rooftop mounted system. An optimally oriented, unshaded system can be expected to produce 900-1000 kWh/kW$_p$ per year, which results in a LCOE of 0.11-0.13 €/kWh [6].

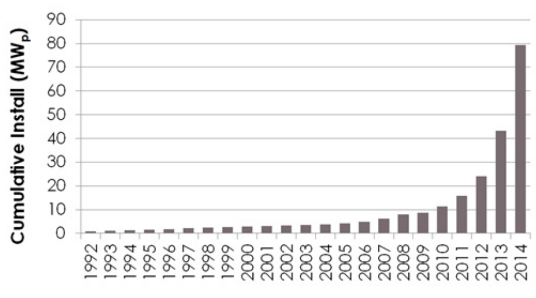

Figure 1: Cumulative PV installations in Sweden [5]

[1] A conversion of 9.5 SEK/€ is used throughout [7]

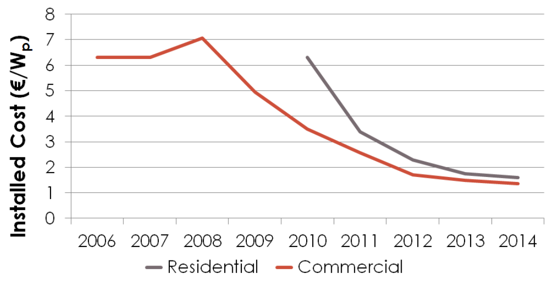

Figure 2: PV installation costs, not including VAT [5]

Another market driver has been the capital rebate subsidy from the government. This program is targeted to micro-producers (i.e. prosumers) and is open to any renewable generation source, although solar PV is the largest application. The rebate program was founded in 2006, but was significantly expanded in 2012 with 22.1 M€ and scheduled to operate between 2013 and 2016. Facilities could qualify for up to a 35% rebate; however the entire budget was exhausted by October 2014. The government refunded the program with 5.3 M€ and now has a 20% maximum rebate. However, a queue of applications has formed and the current budget covers less than half of the applications. In July 2015, the government refunded the program with 47 M€ applicable between 2016 and 2018.

It is also possible for micro-producers (43.5 kW$_p$ and smaller) to earn a tax rebate on overproduced electricity. This policy began in 2015, and gives 0.06 €/kWh up to a maximum of 1900 €/year per tax payer. It acts as a feed-in bonus on top of the wholesale rate typically offered by utilities. A small number of utilities have offered above market rates for overproduced electricity, but it is uncertain how many will continue under the new feed-in bonus. The micro-producer subsidy will be reviewed in 2018 to determine the need for it to continue.

2 CALCULATION METHODOLOGY

The techno-economic analyses presented here use known technical and financial data from each project, and a single prediction for the future electricity market is applied to all cases. Project specific data is listed with each case study, while the common assumptions are described in this section.

All systems are assumed to have a 30 year lifetime, a fixed annual cost that is 0.1% of the total installation cost, and inverter replacement costs of 0.16 €/W_p. The real discount rate is 3%, which corresponds with the current cost of debt in the Swedish market [7].

A probabilistic method is taken towards calculating the economic performance of the systems. Net present value (NPV) is used as the economic metric, and is reported as *probability of profitability*. Profitability is defined as a positive NPV at the end of the system's lifetime, and the probability is the percent of future scenarios which achieve profitability. The *probability of investment recovery* is also reported, which removes discounting and only considers the return of the original investment value. All costs and revenues are included in the NPV except for taxes on the gains from sold electricity (e.g. before taxes). Self-consumed electricity is valued at the retail electricity price, while sold electricity earns the wholesale spot price. Green certificates and the feed-in bonus are earned only on overproduced electricity.

Determining the distribution of results is done using a Monte Carlo analysis, with six stochastically created inputs; annual production, annual demand (which determines self-consumption rate), inverter lifetime, electricity prices, green certificate prices, and where applicable, loan interest rates.

Annual production and demand are considered as normal distributions, with the mean values calculated in System Advisor Model [8] using the nearest available TMY2 climate data, and the standard deviation calculated from historical irradiation measurements [9]. Variations in annual irradiance is relatively constant throughout Sweden, therefore a single standard deviation of 3% of the mean is applied to all cases. An example of the production distribution for Coop C is shown in Figure 3. Each system has a specific number of inverters specified, and each has its lifetime calculated from a Weibull distribution, with 15 years as the expected mean.

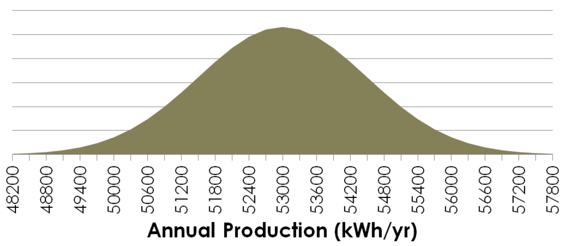

Figure 3: Example of production probability distribution

Prices and loan rates are calculated as a time series using a discretized geometric Brownian motion (GBM) with mean reversion, represented in Equation A. Since the future for the Swedish electricity market is very uncertain, three future price scenarios for wholesale spot prices and retail prices have been created based on energy systems modeling done for Sweden [10][11]. These represent the long term mean (which is the drift term δ_t in Eq. A) and are given equal probability of occurring. The historical prices and the three scenarios are shown in Figure 4. Green certificate prices and loan rates use a constant drift rate. The volatility of each variable is calculated from historical data and assumed to continue into the future at the same value. While it is impossible to show all of the possible time series created by the model, Table I list the input values for the GBM model and a sample for green certificates is shown in Figure 5.

$$P_t = \delta_t + \sigma P_{t-1} W_t + \alpha(\delta_t - P_{t-1}) \qquad \text{Eq. A}$$

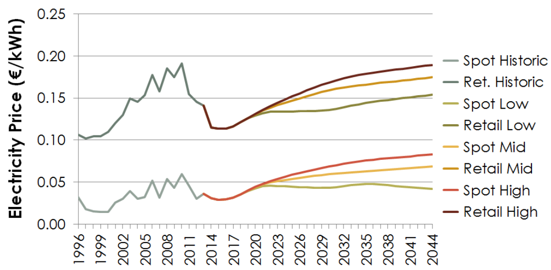

Figure 4: Historic and future electricity prices

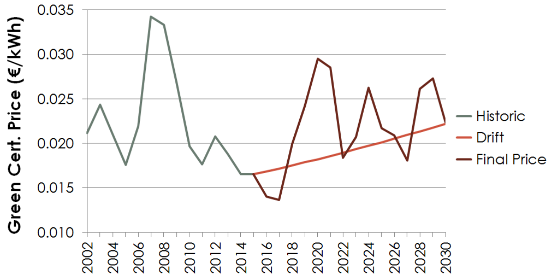

Figure 5: Sample of GBM green certificate price series

Table I: GBM time series input variables

	Drift (δ)	Volatility (σ)	Mean Reversion (α)
Elec. Prices	Fig. 4	0.25	0.55
Green Cert.	P_{t-1}*.02	0.20	0.55
Interest Rate	P_{t-1}*.015	0.13	0.30

All calculations are performed using Microsoft Excel 2010 and use the built-in randomizing function. Analyses are run with 100,000 iterations, which results in a NPV convergence rate of at most 0.0003% relative to the original investment value.

3 OVERVIEW OF THE COOPERATIVES

The cooperatives investigated in this study are spread around central and southern Sweden, represent an array of different arrangements, and use common construction methods for the region. The per-area cost of electricity in each of them is well above the national average (2.17 €/m^2), making a strong motivation to reduce costs [12]. Table II has a listing of the key social characteristics of each cooperative, while Table III includes the energy characteristics of the PV systems.

Table II: Social characteristics of cooperatives

	Built	Dwellings	Board Members
Coop A	1947	60	5
Coop B	1966	546	7
Coop C	1992	16	6

Table III: PV and energy system characteristics

	Size (kW_p)	Production (MWh/yr)	Demand (MWh/yr)	Self-Use
Coop A	115	64	159	55%
Coop B	627	553	1640	70%
Coop C	56	53	136	52%

4 CASE STUDY FOR COOPERATIVE A

Cooperative A has a 115 kW_p system installed on primarily western facing roofs, with one smaller array facing east. A photograph of the system is presented in Figure 6. The non-optimal orientation combined with a high number of roof obstructions has resulted in a relatively low annual production of approximately 560 kWh/kW$_p$. The system cost 1.92 €/W$_p$ for a total of €221,000 (incl. VAT) and they received a 35% capital rebate from the government of €77,700.

Figure 6: PV system at Cooperative A [13]

4.1 Motivation

Cooperative A was looking for ways to reduce their operating costs, which consisted of three major categories; outstanding debts, maintenance, and energy. Since the first two are largely fixed, they decided to go for savings in energy cost, which is dominated by heat supplied by the local district heating utility. Environmental considerations were not a primary driver.

4.2 Process

The first idea was to install solar thermal collectors and make heat directly. However, when discussing this with the utility, they were informed that the reduction in demand would lead to a higher tariff scheme and thus would not make it economical for them. Therefore the strategy switched to PV, which in 2012 was becoming increasingly interesting due to the rapidly rising electricity prices. They wanted to install as large a system as possible, covering the entire west facing roofs, resulting in a 115 kW$_p$ system. To minimize overproduction and sales to the grid, they also created an internal metering structure for apartment loads and have a single utility meter for the grid.

The two executive board members heading up the initiative are professional project managers and engineers at a global manufacturing firm; however they had to hire an external project manager experienced in PV installations to cut through the continuous planning challenges. First, the electric utility told them they could not connect their PV system to the grid, which was false. Next, the municipality planners lacked a routine for permitting PV, and therefore required the roof be replaced to match the color of the modules. Then because permitting was delayed, there was an increased pressure to complete the project in time to receive the 45% tax rebate before it was reduced to 35%. This caused the board to skip the bidding process for contractors, which they believe could have lowered costs by 25-30%.

4.2 Outcome

At the time of the interview, the system had been commissioned for several months, but the board had never carried out any sort of investment analysis for the PV system, only for the original thermal system. The PV project manager believed they would have a 10 year simple payback time. However the dramatic drop in electricity prices, increased project costs, and reduced capital rebate were not considered in the estimate, which will likely lead to a simple payback time of 24-28 years without the micro-producer subsidy. They continue to challenge the utility, who is classifying the system as commercial, which prevents them from qualifying for the micro-producer subsidy. Assuming the program is available for 5 years, the payback time would be reduced to 23-27 years. In all price scenarios, the probability of profitability is 0%. If discounting and the idea of earning a profit are removed, the probability of investment recovery is 78%.

Even with all of the challenges encountered along the way, or even perhaps because of them, the board considers the project a success. They were given honorable mention for an annual solar energy prize from the Solar Energy Association of Sweden.

5 CASE STUDY FOR COOPERATIVE B

Cooperative B has a 627 kW$_p$ system installed across 20 roofs, mostly facing south but with about 35% of the roofs facing west. Annual output is expected to be 885 kWh/kW$_p$. The system cost 1.3 M€ (incl. VAT) to install over the course of three summers, which is 2.07 €/W$_p$, and a 35% capital subsidy worth €455,000 has been received. A photograph of some of the buildings is shown in Figure 7.

Figure 7: PV system at Cooperative B [14]

5.1 Motivation

The idea to install a PV system came from the local office of their affiliated national organization during planning for the replacement of roofs and electric wiring. The repair was planned for all buildings according to the long-term maintenance plan, and the board subcommittee knew PV would be more cost effective since the scaffolding and equipment for the roof would already be on site. The motivations to install PV were two fold; first to reduce operating costs and second to reduce CO_2 emissions.

Before starting the project in 2012, the contractor provided an investment analysis with three scenarios concluding that cooperative B could expect a 5% to 13% internal rate of return (IRR) and a payback period of 8-13 years. This was without consideration for the 35% capital subsidy, but did rely on net metering, which the executive committee was expecting to earn.

5.2 Process

The board hired a local contractor with experience in large scale PV systems to handle the installation, commissioning, etc. While they did not take any other bids, each building had a capped cost and any cost savings made was shared between the contractor and the cooperative. This structure was particularly beneficial to the cooperative since during construction the cost of equipment dropped considerably.

Previously the municipality had only dealt with large-scale PV systems on commercial or public buildings and there was a lack of routines to govern the process for residential buildings. The board became pioneers, working closely with the municipal council to fulfill all of the necessary requirements without undue costs or delays. Overall, the installation proceeded without any major hindrances, which the cooperative attributes to the experience and network of the local contractor.

Since the wiring was also to be replaced, the cooperative took the opportunity to redesign the metering scheme for the apartments. They switched to a single meter per building so that residents saved on fixed fees, and use more PV generation directly in the building. They also installed DC cables between several of the PV and non-PV furnished buildings to reduce the amount of overproduction sold to the grid. The result is that they were able to boost their self-consumption to 70%.

5.3 Outcome

From the time the project started, much has changed in the electricity market. Electricity prices fell by nearly 50% and net metering was replaced with the micro-producer subsidy described above. Cooperative B has been able to take advantage of the micro-producer program by considering each building its own system rather than as a collective, which is made easier since each building still has its own meter.

Regardless of the weakened market conditions, cooperative B still has a 99.9% chance of having a profitable investment even without additional subsidies. The conditions are likely to not be as good as expected, with simple payback time expected to be between 12 and 17 years, and IRR between 4.5% and 6.5%. A formal poll has not been taken, but the board members believe that the cooperative members are happy with the project. They were also given an honorable mention award from the Solar Energy Association of Sweden.

6 CASE STUDY FOR COOPERATIVE C

Cooperative C, shown in Figure 8, has a 56 kWp system installed facing almost due south and on a steep 45° roof. With nearly no obstruction, their position is nearly ideal for Sweden and should expect 950 kWh/kW$_p$ of annual production. The system cost €135,000 (incl. VAT), equivalent to €2.41/Wp, and a 27% capital subsidy worth €36,500 has been awarded.

Figure 8: PV system at Cooperative C

6.1 Motivation

Cooperative C had been built with direct electric resistance heating that was due to be replaced, and the residents were motivated to have a more energy-efficient option. They considered several alternatives before deciding on exhaust air sourced heat pumps. At the same time, a PV system was considered as a way to further reduce operating costs and improve the environmental profile of the cooperative. Environmental concerns were also expressed in the procurement of equipment, as the cooperative required that the panels be sourced from a manufacturer with high environmental credentials (i.e. handling of toxic waste). The executive board also hoped that the lower costs would make the cooperative more attractive to owners, thus lowering the turnover rate and increasing property values.

Investment analysis prior to starting the project was performed by an economist in the local office of their affiliated national organization. It was projected that the system had a net present value of €105,000, nearly double the installation cost.

6.2 Process

With help from their national affiliate, the board put a call out for bids on the PV system and received over 25. This was many more than expected and the process of selecting a final supplier took longer than the board had counted on. The contractor they selected had no previous relationship with the cooperative, but the board was satisfied with their work. Few challenges were met during the installation process, partially due to the close proximity of the cooperative to city hall, which enabled spontaneous meetings and rapid permitting.

In addition to installing the new system, the metering was switched from individual apartments to a single meter for the entire cooperative. Individual metering is still done internally by the cooperative. They also switched to an electric utility which offers better rates to cooperatives and signed a contract with a second utility to sell any overproduction equivalent to the retail rate, effectively giving them net metering.

As is common with major infrastructure works in cooperatives, the new heating and PV systems are 100% financed with a 30 year loan.

6.3 Outcome

The installation of the PV system led to an unexpected social benefit for the cooperative. The long and sometimes intensive process, which necessitated regular meetings and decision making amongst the residents, increased the sense of belonging and brought the community closer together. Residents now participate in more collective activities and the turnover rate has decreased.

The financial outlook is still relatively uncertain. The cost of the loan is very high in the early years due to the straight-line amortization schedule, and combined with the current low electricity prices this means that the PV system is currently costing more than buying from the grid. Assuming that the net metering contract lasts for five years from the commissioning of the system, the probability of profitability is 36%. The probability of investment recovery is 44%. In no iteration of the Monte Carlo analysis did a NPV of €105,000 occur, with the highest value being approximately €45,000.

In interviews after the installation (but before calculation of these results), the chairman of the board suggested that the short term economics were less critical, and that the long term sustainability of the cooperative is more important.

7 DISCUSSION AND CONCLUSIONS

The three case studies presented here offer an insight into the adoption methods of energy technologies in residential cooperatives. The results indicate that reduced operating costs (i.e. a profitable investment) are a primary driver. At the time that the decisions to install a PV system were being made by the boards, the information at hand was believed to be true suggesting that they behaved economically rational, which is their duty as an agent of the cooperative. However, they also lacked expertise in being able to perform detailed techno-economic analyses. In all cases, the owners were presented with a financial analysis from an outside party; in two of the three cases the analysis was provided by a contractor installing the system; in one case the economics were simply estimated and no calculations were ever made.

Unforeseen economic conditions, such as higher installation costs or lower electricity prices, have not dissuaded the boards from considering their projects a success. This suggests that non-economic factors are either more important than original stated, or that behavior bias in the form of anchoring, provides part of the explanation given that they now have an installed PV system. Several cooperative boards mentioned the desire to "do the right thing" with regards to the environment. Sweden ranks highly as a society which is keenly aware of environmental issues [15], and a PV system is a clear signal from a cooperative that they are taking a noble action. Two of the three cases presented here have been given awards by the Solar Energy Association of Sweden for their pioneering efforts, reaffirming that they have taken the right action [16]. It may also be the case that the cost of removing the systems is higher than the potential losses, and since they have no control over the development of the market they must find ways to be happy with their decision and promote it as a good thing for the cooperative.

The boards expect that the non-economic benefits described here will eventually be transformed into economic benefit through higher property prices, but this effect is highly uncertain and difficult to include in a formal economic analysis. The social benefits experienced in cooperative C, while significant and important to the overall wellbeing of the cooperative, are equally difficult to quantify.

These cases highlight the challenges that can arise with first adopters, and that there is a need to increase knowledge amongst non-expert potential owners of energy technologies. This is particularly true in the case of Sweden, where the deregulated market makes long-term forecasting difficult even for experts. While there are only a limited number of cases presented here, they have shown that non-economic incentives to PV adoption are significant, but may be stronger after the installation has been made. These case studies are useful for others involved with community based PV systems and those interested in technology diffusion.

8 ACKNOWLEDGEMENTS

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