On the economic effects of metering schemes in community owned residential PV systems

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Abstract

Community-owned, grid-connected solar photovoltaic (PV) systems in multi-family housing offer the potential for large scale installations with favorable costs as compared to single family systems. However, traditional utility metering schemes often define boundaries which result in high sales of PV generation to the grid, lowering the economic value for the cooperative. This study explores two alternative metering schemes which better represent the interests of cooperative as a single PV owner by aggregating meters within and across buildings. Measured communal load data from a cooperative in western Sweden is combined with modeled PV generation and apartment load data to calculate the net present value (NPV) of the various meter schemes under several subsidies policies. The results show that under a traditional metering scheme, 40% of the PV generation is considered sold to the network, even though only 3% of the electricity physically leaves the buildings and none leaves the estate. Reclassifying this sold electricity as self-consumed results in an increase in NPV by as much as €60,000, which is €15,000 more than the value added by subsidies. The results of this paper are useful for community organizers, PV installers, utilities, and lawmakers interested in next generation electricity markets based on distributed generation.

Keywords: *Community solar, cooperative, self-consumption, techno-economic, utility 2.0*

1. Introduction

Multi-family housing cooperatives, such as those common in Scandinavia, have the potential for procuring large, commercial scale (30-700 kW_p) solar photovoltaic (PV) systems as a single project. These types of installations can mean increased rates of PV deployment at lower costs, but coordinating many households into an economically optimal configuration presents multiple challenges. Traditional electric utility billing structures are based on a single meter per household, so when a single PV system covers the roof of many independent meters they may not be able to access the PV generated electricity. Likewise, cooperatives often consist of multiple buildings, each with their own meter, meaning buildings with PV cannot easily share it with those that do not. This internal metering division of the cooperative can lead to high volumes of PV overproduction sold to the grid, which is economically detrimental when net metering or feed-in tariffs are not present.

Using the case of a large cooperative in western Sweden, this paper quantifies the economic effects of an internally segregated metering scheme within a single PV system owner. Two integration schemes are introduced, horizontal and vertical, and are compared with the default metering conditions. The techno-economic analysis is performed using metered load data, simulated PV production, and comparisons are made using NPV. The metering schemes are also contrasted to the economic impacts of the three primary subsidy policies for distributed PV in Sweden. The results are followed with a discussion of techniques cooperatives can and have used to desegregate their metering, their limitations, and potential for improvement. The motivation for this work is to highlight the need for solutions, whether technical, political or entrepreneurial, which can lower the barriers to community owned PV systems.

2. Background

This section provides background information regarding the structure and operation of cooperative housing in Sweden, and the context of greater electricity and PV markets which investments must be considered.

2.1 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 (Statsitics Sweden, 2012). 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. The annual

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fee is determined on a per square meter basis, meaning larger apartments pay larger fees. A well maintained building with low operations costs results in higher property values and thus higher returns for the owners. Therefore cooperatives have an incentive to invest in cost-reduction schemes, such as self-generated electricity, in order to 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, while apartments have their own meters and purchase electricity from the retailer of their choice. It is also possible for apartment electricity to be included in the communal fee, particularly if there is electric heating which dominates the load. 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. This structure has the advantage of reducing fixed grid fees, which are highest for apartments due to their relatively low demand.

2.2 The 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 (Swedish Energy Agency, 2015). The annual demand is typically 140-150 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 wish. 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 (Ei, 2015).

When Sweden joined Nord Pool in 1996, the average spot that first year was 0.032 €/kWh. Immediately after prices fell to 0.015 €/kWh and stayed there until 2001, when prices rose rapidly and became more volatile. Since 2013, there has been relatively low demand and considerable oversupply such that prices are now back to the same level as 2001(Nord Pool Spot, 2015). Low price combined with unfavorable government policy, has caused two large utilities, Vattenfall and E.On to announce early retirement of four of their oldest reactors, set to close by 2020 (World Nuclear Association, 2015; World Nuclear News, 2015).

To support renewable energy development, Sweden has a quota system, known as green certificates, which is accessible by any renewable source. 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 (Swedish Energy Agency, 2015).

2.3 The Swedish PV market

Relative to many other countries in Europe, the Swedish market for solar PV is small. In 2014, 36.2 MW_p were installed for a cumulative total of nearly 80 MW_p (Lindahl, 2015). As shown in Figure 1, the market has been growing rapidly in recent years in conjunction with rapidly dropping in costs, which are currently 1.3–1.6[1] €/W_p (excluding VAT) for a rooftop mounted system. A well oriented, unshaded rooftop system can be expected to produce 900-1000 kWh/kW_p per year, which results in a LCOE of 0.11-0.13 €/kWh (Stridh et al., 2014).

[1] Original price figures are in Swedish crowns (SEK) and converted to Euros (€) using a 9.5 SEK/€ exchange rate throughout (Sweden Central Bank, 2015).

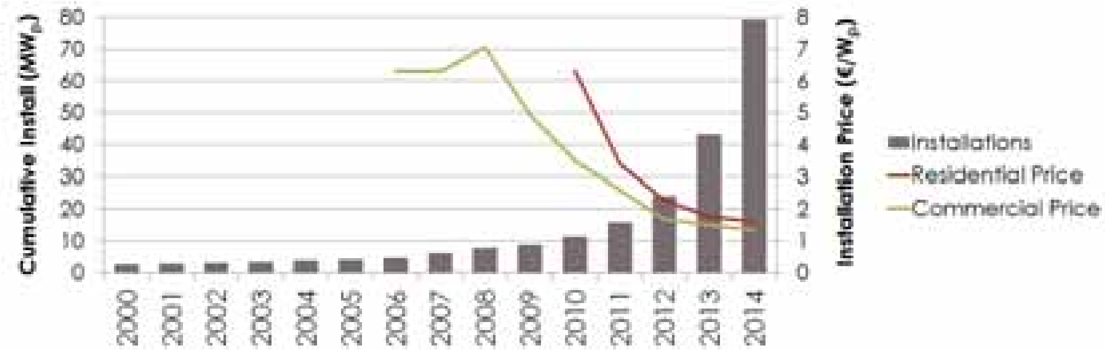

Fig. 1: Cumulative solar PV installations in Sweden (MW_p) and installation prices (excl. VAT) (€/W_p)

Another market driver has been the capital rebate subsidy which has been available at various levels from the national government since 2006. In 2009 the program was rewritten to include any micro-generation system, gave a 45% rebate on total installation cost, and was scheduled to run through 2011. This was eventually extended through 2012 and then rewritten with a new budget awarding a 35% rebate to run from 2013 to 2016 (Lindahl, 2015). The budget for this program was exhausted in 2014 and a queue of 3400 applications formed (Swedish Energy Agency, 2014). The program was modestly refunded in early 2015 (without enough to cover the queue) and the support reduced to 20% of total costs. The latest government budget proposal has once again refunded the program for the long term (2016 to 2019) and the support reduced 15%.

Building applied PV systems are subject to the same deregulated market as any other generator, so it is common for utilities to pay the wholesale market price for overproduction. One support measure allows micro-producers/prosumers (43.5 kW_p and smaller) to earn a tax rebate on overproduced electricity. This policy began in January 2015 and acts as a feed-in bonus, giving 0.063 €/kWh up to a maximum of 1900 €/year per tax payer. A small number of utilities have offered above market rates for overproduced electricity, but contracts are usually short term and 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 (Lindahl, 2015).

3. Methodology

The default meter configuration for this study assumes a cooperative has multiple buildings, each with its own meter on a communal electricity account. The apartments are all metered independently with separate accounts. The vertical expansion in metering occurs within a single building and combines all of apartments with the cooperative's meter. A horizontal expansion occurs between buildings, where the cooperative's individual meters can be aggregated as if they are one large meter. The two expansions are also combined, where the entire cooperative acts as a single generation source and electricity load. A graphical representation of the concepts is shown in Figure 2. In all cases, the same PV system is installed and the same load profile is present, only the way in which the boundaries for the metering are drawn changes.

Fig. 2: Diagram of the horizontal and vertical meter expansion concepts

3.1 PV production and building loads

The input values for this study are based on a cooperative in the western Swedish city of Gothenburg. There are 312 apartments divided into 13 buildings, six of which have 16 kW_p PV systems on their roofs. PV production is generated using the CEC performance model in System Advisor Model (National Renewable Energy Laboratory, 2015) using TMY2 weather data. The PV system model inputs are listed in Table 1.

Tab. 1: PV system inputs for SAM

Variable	Value	Note
Weather data	Göteborg Landvetter airport	TMY2
Modules	IBC Polysol 250 DC, p-Si	64 per array (384 total)
Inverter	SMA 15000TL-10	1 per array (6 total)
Azimuth (γ)	180°	-
Tilt (β)	30°	-
Degradation rate	0.5%	(Jordan and Kurtz, 2013)
System losses	10.0%	Annual average

Measured communal load data for 2013 and 2014 for the six PV equipped buildings has been supplied, several of which also have laundry rooms. The remaining buildings are assumed to not have laundry rooms. The load data from one of these buildings has been supplied and is multiplied to represent the remaining unsupplied meter data. The final load curve is an average of the two years of measurements. All production and building loads are considered on an hourly basis, which is necessary to determine the self-use fraction. The communal and apartment load data, along with the first year solar production is shown in Figure 3. First year solar production is 970 kWh/kW_p.

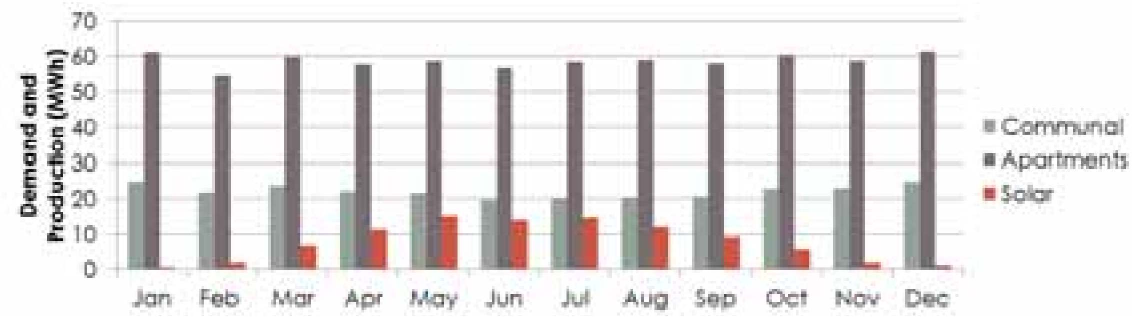

Fig. 3: Monthly data for all communal and apartment loads and solar PV production

Apartment loads are constructed using the Markov chain model developed by Widén and Wäceklgård (2010) which is based on measured plug loads of several hundred households. Since their model is stochastic and this study is deterministic, a single, unique load profile for each building is generated and used across all cases. Demand from the apartments is approximately 2260 kWh per apartment per year.

3.2 Economic calculations

Comparisons between the schemes are done with net present value (NPV, Eq. 1Eq. 1Eq. 1) using traditional deterministic engineering economics. Costs (C) can be divided into one-time and reoccurring costs, seen in Eq. 2. One-time costs include installation cost (I_0) and VAT tax (T_0), while reoccurring costs include fixed operations and maintenance (O&M, OM_t), inverter replacement (IR_t), financing interest, and taxes on the sale of electricity. This study is done assuming self-financing, and is presented before income taxes. Benefits (B) also have one-time and reoccurring components, shown in Eq. 3. The one-time capital subsidy (S_0) is assumed to be awarded in year zero, while reoccurring benefits include; the value of differed electricity purchases (self-consumption, Q_dP_r), the value of sold electricity (overproduction, Q_oP_w), and the value of meter subsidies (Q_sP_s). Inflation is not considered; therefore the discount rate (d) is real. Table 3 lists a summary of all economic input values.

$$NPV = \sum_{t=0}^{L} \frac{C_t + B_t}{(1+d)^t} \qquad \text{(Eq. 1)}$$

$$C = I_0 + T_0 + \sum_{t=0}^{L}(OM_t + IR_t) \quad \text{(Eq. 2)}$$

$$B = S_0 + \sum_{t=0}^{L}\left[(Q_d P_r) + (Q_o P_w) + \sum(Q_s P_s)\right]_t \quad \text{(Eq. 3)}$$

Tab. 3: Economic variable input values

Variable	Symbol	Unit Value	Absolute Value
Installation Cost	I_0	1.36 €/W_p	130,360 €
VAT	T_0	25% of I_0	32,590 €
Capital Subsidy	S_0	15% of I_0+T_0	24,440 €
Fixed O&M (Year 1)	OM	0.25% of I_0	325 €/yr
O&M Cost Escalation Rate	-	1%/year	-
Inverter Replacement Cost	IR	0.157 €/W_p	2525 €/inverter
Inverter Lifetime	-	15 years	-
System Lifetime	L	30 years	-
Real Discount Rate	d	3%	-
Retail Price (Year 1)	P_r	0.098 €/kWh	-
Wholesale Price (Year 1)	P_w	0.021 €/kWh	-
Green Cert. Price (Year 1)	P_s	0.016 €/kWh	-

Future electricity prices are taken from a policy comparison study for Sweden modeled with Times/Markal (Profu, 2014). The wholesale prices for the four scenarios as well as the historical annual averages are shown in Figure 4 (Nord Pool Spot, 2015). All scenarios are assumed to have an equal chance of occurring, and are therefore averaged together. Retail prices (P_r) are calculated each year based on the wholesale price, renewable support subsidies, network fee (0.021 €/kWh), electricity tax (0.030 €/kWh), retailer markup (0.005 €/kWh), and a 25% VAT applied to the sum. Network fees and electricity taxes are assumed to increase at 1% per year, which is relatively conservative compared to the historic rates (Svensk Energi, 2015). Retailer markup and VAT remain constant.

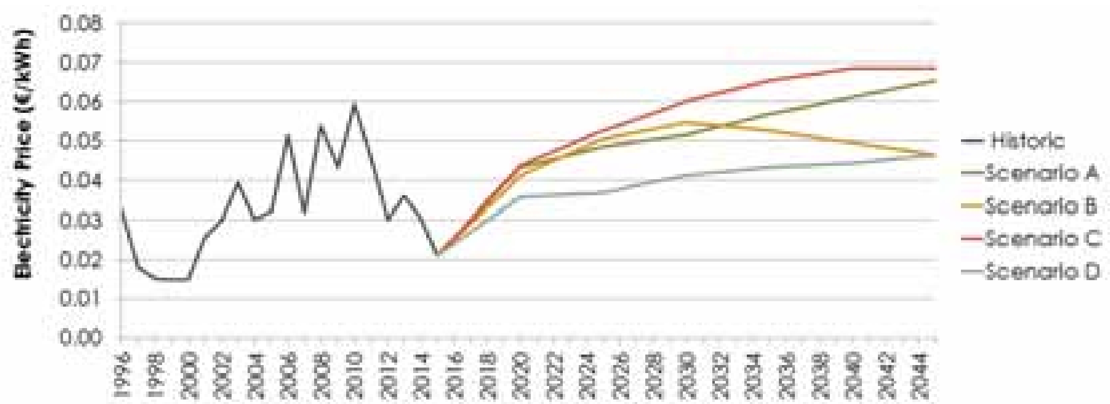

Fig. 4: Wholesale electricity price (P_w) history and future scenarios prior to averaging

3.3 Policy cases

Four policy cases are compared based on the three primary subsidies for solar PV in Sweden. The first case considers no subsidies, and the following cases are built by cumulatively adding another subsidy. The subsidies are added from the most secure (i.e. the subsidy most likely to remain long term) to the least, starting with green certificates, then the capital subsidy, and finally the feed-in bonus. Green certificates and the feed-in bonus only apply to overproduction, making $Q_s = Q_o$ in Eq. 3. The current price for green certificates is 0.016 €/kWh, which is assumed to return to the historic mean (0.022 €/kWh) by 2020 and remain at that level for the remaining 10 years which the system qualifies (Swedish Energy Agency, 2015). The feed-in bonus is assumed to be renewed until 2020, making it a 5 year program. The capital subsidy is 15%, which matches the most recent update to the policy.

4. Results

The motivation for the alternative metering schemes is to increase the self-consumption rate, which is shown for each scheme in Figure 5. It can be seen that the vertical scheme has a greater impact on self-consumption than the horizontal, due to the apartments demanding twice as much electricity as the communal loads. It can also be seen that the combined scheme has a 100% self-consumption rate, meaning that none of the electricity generated on the cooperative's estate physically leaves it, even though the meters indicate otherwise.

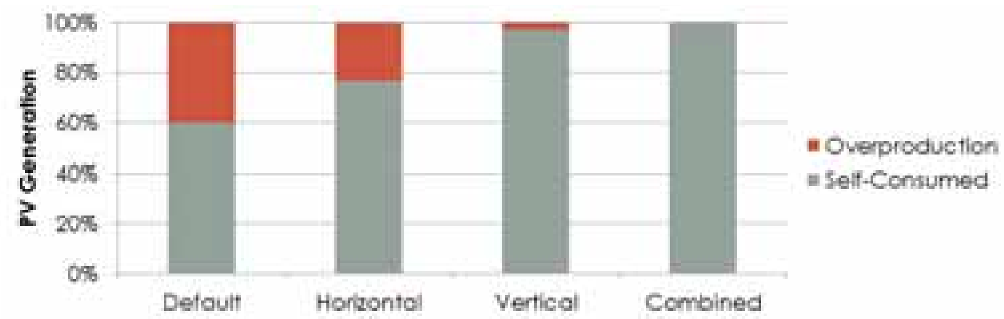

Fig. 5: Self-consumption rates between metering schemes

The effect of self-consumption on the profitability can be significant, as Figure 6 shows. The vertical scheme adds over €60,000 of value to the PV system, significantly more than any of the subsidies which only add about €44,000 put together. The horizontal scheme adds over €27,000, nearly €3000 more than the capital subsidy. As would be expected, the green certificates and feed-in bonus becomes less significant with less overproduction. In the horizontal scheme they each add about €6000, become less than €1000 in the vertical scheme, and reach zero in the combined scheme.

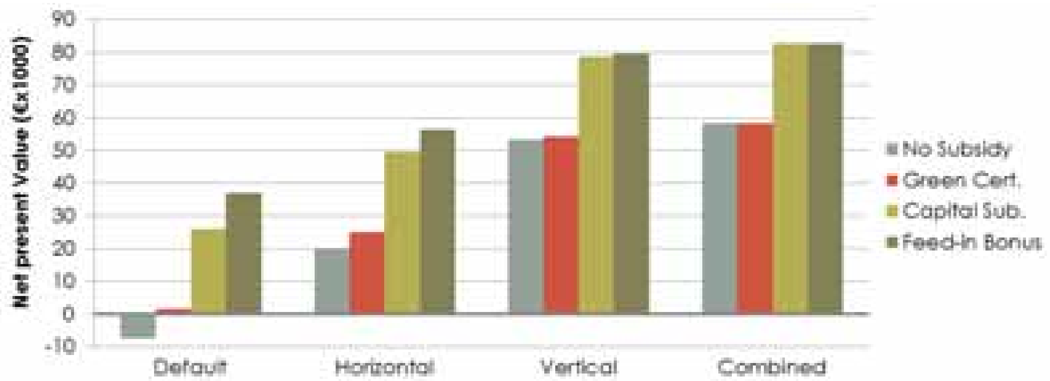

Fig. 6: Net present value of each meter scheme under the various subsidy policies

If this cooperative were to make a PV installation decision using this information only on economic rational, only the default, no subsidy case presented would be rejected. The production conditions here are relatively good, with the system oriented at nearly the optimal position and completely unshaded. Naturally these conditions do not exist everywhere. To extract these results to a more general case, the effects of a range of self-consumption and annual production values on specific NPV (€/W_p) are shown in Figure 7, without subsidies, using the same inputs presented above. The break-even line can be seen between the dark red and black contours, which will move down and to the left as installation costs decrease.

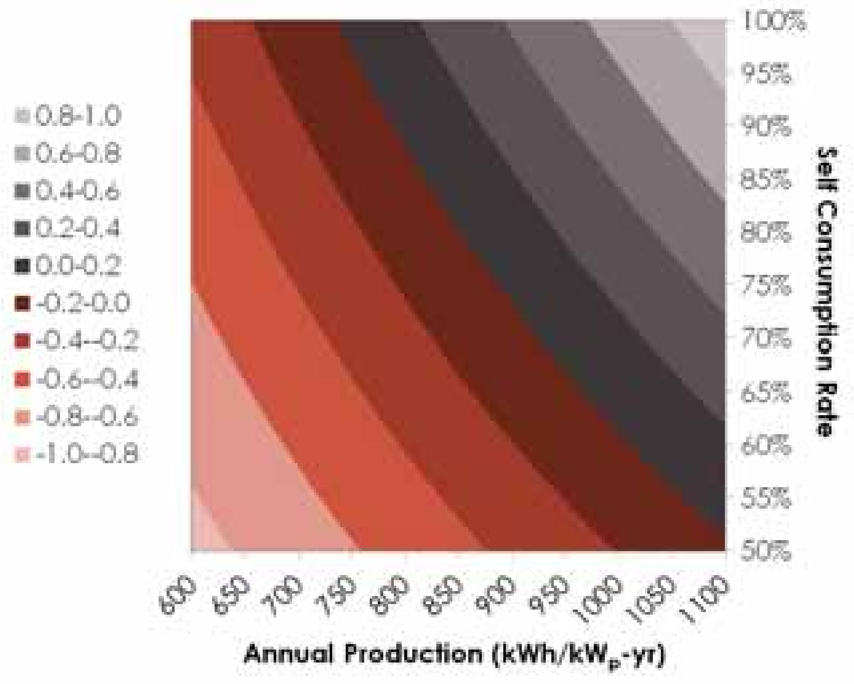

Fig. 7: Specific NPV (€/W_p) as a function of annual production and self-consumption rate

5. Discussion

The benefits of removing internal metering divides in cooperative housing can be clearly seen in the results. This is certainly known to cooperatives who have installed large scale solar PV systems, as there are examples of vertical and combined metering across Sweden (Sommerfeldt and Muyingo, 2015). However, for a cooperative which is currently using default metering, expanding the metering schemes requires overcoming some barriers.

Vertical metering schemes are actually not entirely uncommon in Sweden as mentioned in the background. However the majority of multi-family houses would need to convert, which requires replacing the utility's meters with cooperative owned versions which are then used for internal billing. The cost of this conversion would be approximately €35,000, which is nearly half of the benefit of switching to the vertical scheme, plus the cost and effort of administration over time. Also not accounted for in the results is the benefit of lower fixed network fees, since apartments typically have much higher fixed fees than high demand customers. This value varies significantly by location and should be considered on a case basis.

Expanding the metering scheme horizontally can be considerably more difficult. With the current system, the only way is to physically connect buildings behind the utility meter so that PV generation can be shared between them. Naturally, costs for this will vary depending on the current wiring and if any new wiring needs to be done internally or externally to the buildings. In one case, a large cooperative buried DC cables between the buildings. Given that this measure is taken only because of the location of the meters, one might consider the added cost and materials is unnecessary.

The results presented here indicate that there is a significant amount of PV value being captured by utilities due to the location of meters, and not because of any added service. At the same time, state sponsored subsidies are supporting PV development that may not be necessary in some cases if the meter barriers are lowered. The idea that electricity could be generated and shared between neighbors, across meters, is not particularly novel, but does go against the interests of the utilities who own those meters and the control the structure of the current system. The current technological solutions are expensive and could be considered wastefully unnecessary infrastructure. Restructuring the electricity market and tax code to enable more fluid buying and selling directly between prosumers, combined with ICT solutions, may make it possible to reduce or eliminate subsidies faster. The example presented here is within the well-defined boundaries of a cooperative, but the concept can easily be expanded to neighborhoods, districts, or even cities if the electric network can manage. Reaching a sustainable electricity market built on central and distributed generation sources, utility 2.0, should be a goal for many utilities, citizens, and politicians motivated to develop solar PV.

6. Acknowledgements

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