[*ECONOMIC VIABILITY OF LOCAL ENERGY COMMUNITIES: A SPECIAL FOCUS ON PV AND DIFFERENT SETTLEMENT STRUCTURES*]

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Overview

Until recently, regulatory or legal obstacles prohibited the sharing of photovoltaic (PV)-produced electricity. Fortunately, countries like Austria, Germany and Switzerland in the meantime managed to adapt their regulatory frameworks such that PV electricity sharing is at least possible at a building level, paving the way for the age of local energy communities. Generally, local energy communities (LEC) can be subdivided into three different scales: small-scale LECs at a single-building level, medium-scale LECs at a neighbourhood level and large-scale LECs, which comprise larger areas like villages or even cities. As small-scale LECs are already feasible, the implementation of medium-scale LECs is the next step towards a decentralised and sustainable energy system. Therefore, this study aims at assessing the profitability of PV systems for medium-scale local energy communities in comparison to their profitability for individual buildings. In this way, the actual value of a LEC can be evaluated.

Methods

A mixed-integer linear optimisation model is developed in order to assess the profitablilty of implementing different kinds of PV systems, building-attached and building-integrated, on different parts of the building skin. The objective is to maximise the net present value (NPV) within a 20-year time horizon. The developed model allows to consider buildings individually as well as a local energy community including an arbitrary number of different buildings and building types. As the value of a LEC can differ from location to location, four different settlement patterns are predefined for analysis: a multi-apartment building area (living area in medium-sized or large cities), a historic area (buildings under monumental protection), a mixed-area (suburbia, a mix of multi-apartment buildings and single-family homes) and a rural area (geographically spread-out single-family buildings). A building pool of 10 buildings is assigned to each of these four settlement patterns. Each building can be customized by selecting characteristics like heat load, installed heating system, purely residential or businesses included, adjacent to other buildings or stand-alone, etc.

Results are calculated for three different case studies per settlement pattern. In the first case study, a selection of 5 buildings out of each building pool is considered. The profitability of PV systems is determined along with optimal PV system sizes for each of the five buildings individually (Case Study (i)). In a second case study, the five buildings form a LEC. Profitability and optimal PV system sizes are determined once again (Case Study (ii)). In a third case study, the whole building pool of 10 buildings is taken into account when setting up a LEC (Case Study (iii)), whereas it is assumed that only five provide their roof and façade areas for PV installation.

Results

Results for the optimal PV system sizes and corresponding cost saving potential of PV implementation for individual buildings and the two types of LECs described above (Case Study (ii) and Case Study (iii)) vary significantly when considering different settlement patterns:

<u>Rural area:</u> The cost saving potential of implementing building-attached PV for individual single-family buildings (Case Study (i)) in rural areas is quite low - with less than 2%. In case 5 single-family buildings form a LEC (Case Study (ii)), the cost saving potential can be augmented to more than 8%. Thus, the worth of the LEC can be determined to be more than 6%. Considering the whole building pool (Case Study (iii)), a cost saving potential of 7% is achieved.

<u>Multi-apartment building area:</u> In comparison to the rural area, the cost saving potential of individual multi-apartment buildings (Case Study (i)) is significantly higher - with more than 8%. When considering a LEC of 5 multi-apartment

buildings (Case Study (ii)), cost savings of almost 12% can be achieved. The actual value of such a LEC can therefore be determined to be 4%. Considering the whole building pool of 10 multi-apartment buildings (Case Study (iii)), 10% of costs can be saved.

When the results for the rural and multi-apartment building areas are compared, it becomes obvious that the value of a LEC is higher for rural areas. This can be explained by synergy effects between load profiles: Multi-apartment buildings profit from synergy effects between individual apartment load profiles right away, wherefore the cost saving potential is already high for PV implementation in individual multi-apartment buildings. In a rural area, synergy effects arise only when a LEC is established, wherefore - a LEC has a greater value. Although PV systems can theoretically be implemented building-attached on the roof and façade, the optimisation ignores the possibility of façade PV implementation due to reduced solar irradiation and thus lower profitability compared to on-roof solutions. The cost saving potential is reduced when considering a building-integrated implementation of PV, as is done for the historic area with protected buildings. A building-integration of PV comes with additional basic roof/façade renovation costs due to the violation of the building envelope.

For a first sensitivity analysis, the impact of a battery storage facility is examined. In case of investment costs of 1000€/kWh, the optimisation model determines that the storage is not profitable. However, when considering costs of 500€/kWh a battery storage is determined profitable. For the case study of 5 buildings forming a LEC in the multi-apartment building area, a storage capacity of 25kWh would be cost-optimal. The cost saving potential, however, is low when considering the absolute values of the NPV: a community battery storage can save costs of less than 3000€ in 20 years. This amount has to be divided by 5 buildings with 10 to 20 apartments each. Therefore, the cost saving potential of each inhabitant is negligible.

In a second sensitivity analysis, a heating system change from gas to a heat pump is examined for individual buildings as well as for LECs. Heat pumps are the most cost-intensive heating technology to be installed. Therefore, heat pumps are not competitive with conventional heating systems like gas. When neglecting cost-effectiveness and considering the electrification of the heating sector on a large scale, it would be necessary for PV systems to do their bit to cover part of the load. Therefore, the ability of a PV system to cover load during peak-load times is assessed: In the case that the heat load is not electrified, PV systems are able to contribute to load coverage during peak times significanty (on average 30%, up to 50%). However, when heat pumps are installed and therefore the heat load is electrified, the peak load times are shifted and the PV contribution decreases significantly to less than 15%.

Conclusions

Results prove the establishment of local energy communities profitable for all settlement patterns considered in the analyses presented in this study. However, the value of a LEC varies for the different settelement patterns and is smallest for a historic area because of the assumption of implementing PV systems building-integrated instead of building-attached. The reasonableness of the heating sector electrification on a large scale is questionable as results confirmed the insignificant contribution of PV to covering the combined load (conventional electricity demand and electrified heat demand) during peak-load times. This would then require fossil fuel plants to cover residual load.

As small-scale local energy communities at a building level are already allowed in some countries, the focus in the near future should be on establishing medium-scale communities in neighbourhoods in order to keep pace with the development towards a decentralised, renewable energy system. Despite proven profitability of PV systems at a neighbourhood level, additional financial incentives might be necessary to motivate early adopters of this promising concept.