COMBINING SIMULATION AND OPTIMIZATION FOR OPTIMAL ENERGY COMMUNITY PLANNING WITH TECHNOLOGY DIVERSITY AND MULTIPLE OBJECTIVES

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Overview

The *Clean Energy for All Europeans Package (CEP)* [1] adopted in 2019, presents an update of the European Union's (EU) energy policy framework with the goal of refraining from fossil fuel usage, reducing CO2 emissions and moving towards a cleaner energy future. The CEP comprises eight directives out of which two contain regulatory guidelines for renewable energy communities (RECs) and citizen energy communities (CECs). Even though EU member states were supposed to transpose these supranational guidelines into their national legislation within 1-2 years, Austria is still one of the few countries already providing the corresponding legislation for RECs and CECs since July 2021 as part of the *Renewable Energy Expansion Act* [2]. Both, RECs and CECs, have the potential to play an important role in pushing the energy transition forward. To maximize the benefits gained from their establishment, an optimal planning process is essential. Whether a local authority wants to establish an energy community or whether a new positive energy district is being planned, or, most importantly, whether private persons intend to engage in the concept of energy communities, the interdisciplinary collaboration of various stakeholders is needed. Therefore, not only a great variety of technical components have to be considered in an impactful planning tool, but also a number of different objectives such as the minimisation of costs and CO_2 emissions, or the maximization of PV self-consumption.

Methods

To optimally support the planning process of energy communities regarding different objectives such as cost and emission minimization, maximization of self-consumption and else, a model is developed that interlinks a simulation and optimization approach to combine the best of two worlds . The core of the model is a linear optimization model where a variety of different technologies is modeled from a system perspective. The outcome is the ideal energy flows – with respect to the chosen optimization objective – within the community. The so detemined 'schedule' is then passed on to the detailed simulation of the individual technologies, which will then in return adjust the assumptions of the optimization. This modification is needed because of the different degree of accuracy between optimization and simulation. For example, while the optimization consideres battery charging, discharging and stand-by losses, the precise reproduction of a storage system for the simulation takes many more aspects, such as reduced capacity due to battery aging, into account. Therefore, a discrepancy between the state of charge assumed by the optimization and the state of charge calculated by the simulation can occur. Thanks to this approach of rolling wave planning, the gap between scratching only the surface of the problem due to significant abstraction levels (optimization model) and long computing time because of the interplay of too many components modeled in great detail (detailed simulation), is bridged. In a downstream process, the economic aspects such as return on investment, amortization as well as optimal capacities of the generation units and number of individual components (for example how many kWp of rooftop photovoltaics or how many heat pumps need to be installed within the community) can be determined with regard to different objectives.

The proposed model not only contributes to the current state-of-the-art by a combination of optimization and simulation, but also by taking into account a variety of different technologies in the electricity and the heating sector:

- Rooftop photovoltaics
- Electric vehicles
- Heat pumps
- Storage systems (electricity, thermal)
- Solar thermal systems
- Biomass generation units

- Utilization of waste water

In order to validate the developed model, two use cases are developed. One use case is specified for a rural and one for an urban region. This way, the decision process on the mix of different technologies meeting regionally varying needs can be highlighted.

Results

The model aims to determine optimal capacities of the generation units as well as the number of individual components. At the same time, a number of goals for the considered energy community can be specified, such as cost and emission minimization or maximization of self-consumption. Results show that for the objective of minimizing CO_2 emissions or maximizing the self-consumption larger capacities of rooftop PV are considered optimal. When aiming for minimal CO_2 emissions, the purchase of electric vehicles as well as the installation of heating systems based on renewable energies is prioritiesed. Therefore, it is important to balance the increased electricity need with an according capacity of PV systems. Merely maximizing the PV self-consumption leads to a reduction in additional electricity consuming technologies. This emphasizes the need for a downstream process to re-evaluate the results not only in terms of economic aspects but also to reconcile the findings with the climate objectives. In comparison, as for the objective of cost minimization, optimal PV system capacities are usually smaller; however, this also depends on the assumed price for electricity purchase from the conventional supplier as well as the investment costs for PV systems. Due to the current high end-user prices, PV system installation increases in profitability, thus also optimal PV system capacities rise.

Due to the naturally limited rooftop areas, the technology combination of rooftop PV competes with the installation of solar thermal systems which can also be used providing warm water and as heating support. Here, the optimal combination also depends on prices for electricity and alternative heating systems.

Results show that the combination of optimization and simulation is well coordinated such that they complement each other. While the optimization works from a system perspective, the detailed simulation of individual technologies accounts for involving aspects such as changes in temperature or battery aging. Therefore, this approach adds value to the problem of optimal planning in the sense that it adds a great proximity to the interactions of technologies, to show not only how they function in theory but also once the energy community is established.

Conclusions

The benefit of energy communities in general is obvious: reduction of CO_2 emissions, greater independence of market prices and cost savings in the long run for participants. Thanks to an optimal planning process, the optimal capacities of PV systems as well as their orientation, optimal capacities of other technologies, and finally the optimal technology mix can be determined for different objectives. With the interaction of individual technologies increasing, it becomes more complex for citizens to understand the details, which can hamper the motivation to further invest in renewable energy technologies. A visual assessment based on the results of the here-developed model can also have an educational effect on stakeholders, and especially private persons, not only to encourage them to invest in a greener future but also to show explicitly that objectives such as self-sufficiency are economically feasible.

References

[1] European Commission, 2019. Clean energy for all Europeans package; https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

[2] RIS, BMDW: “Renewable Energy Expansion Act”, 2021 (Novelle 2022). URL (last accessed 29/03/2022): ERV_2021_1_150.pdf (bka.gv.at)