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Influence of PV battery and thermal storage systems using heterogeneous demand patterns

Geert Litjens *, Ernst Worrell, Wilfried van Sark

Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands

Email: G.B.M.A.Litjens@uu.nl , B.B.Kausika@uu.nl

Introduction

Photovoltaic (PV) systems are a promising solution for local generation of electricity, especially in urban areas. Excess PV energy can be stored in batteries or can be converted with a heat pump to heat for thermal storage. However, little is known about the impact of the PV systems with combined electricity and thermal storage on the PV **self-consumption rate (SCR)** and annual benefits. Hence we analysed these impacts using different PV energy storage combinations.

Method

We used 400 Dutch residential demand profiles containing electricity and heat demand patterns were estimated from measurements conducted in 2008 for a 15 minute time scale. The electricity patterns were scaled to an annual consumption of 3,150 kWh. PV yield patterns were modelled with a module azimuth of 180° and a tilt of 37° using the open source package PVLIB [1]. Ground source heat pump electricity demand was modelled to generate 15,000 kWh heat annually (≈600m³natural gas), 11,250 for space heating and 3,750 kWh for tap water heating.

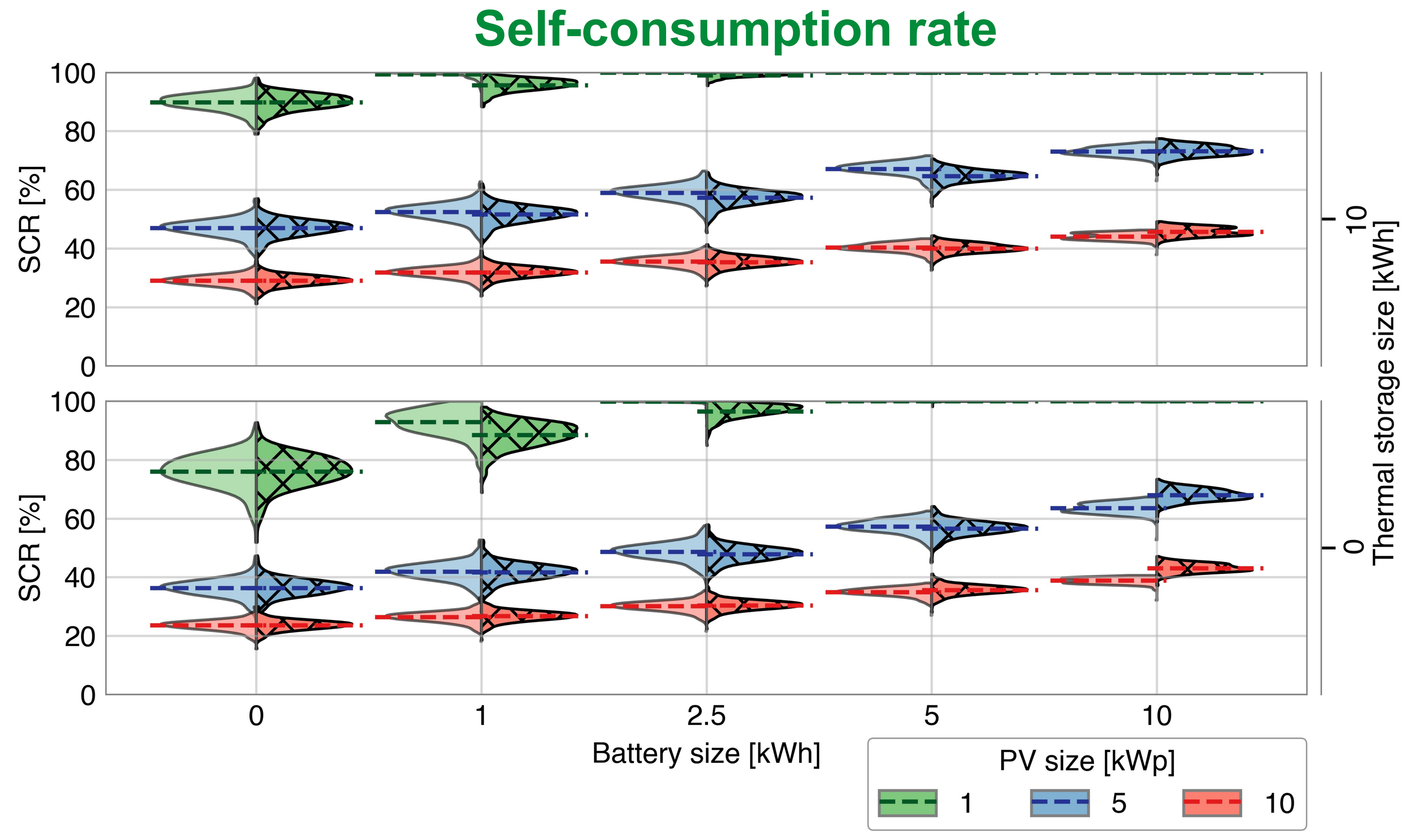
Two storage algorithms were compared; the **battery priority algorithm (BPA)** and the **thermal priority algorithm (TPA).** The **BPA** algorithm prioritizes battery storage over thermal storage whereas the **TPA** prioritizes thermal storage over battery storage. Charging and discharging of the battery was modelled using a simple control strategy, presented in previous research [2].

The wide range of consumption patterns provides insides on the relation and sensitivity of PV systems combined with electricity or thermal storage, or a combination of both. We used violin plots to show the distribution of the results.

Conclusions

- Larger **SCR** for the **BPA** algorithm compared to the **TPA** algorithm.
- Battery storage has a larger impact than thermal storage on PV self-consumption, even if the thermal storage is 10 times bigger.
- Battery storage has a higher flexibility than thermal storage, since battery storage can provide the electricity demand for the heat pump.
- Wider distribution ranges of **SCR** are shown for smaller PV systems than larger systems, related to the larger time-of-use overlap between energy production and consumption.
- Energy storage reduces the distributions range of the presented results. The influence of the individual demand patterns decreases.
- Annual financial benefits from PV systems with either battery storage, or thermal storage are larger for each kWh of individual storage technology, compared to the combination of the storage technology.

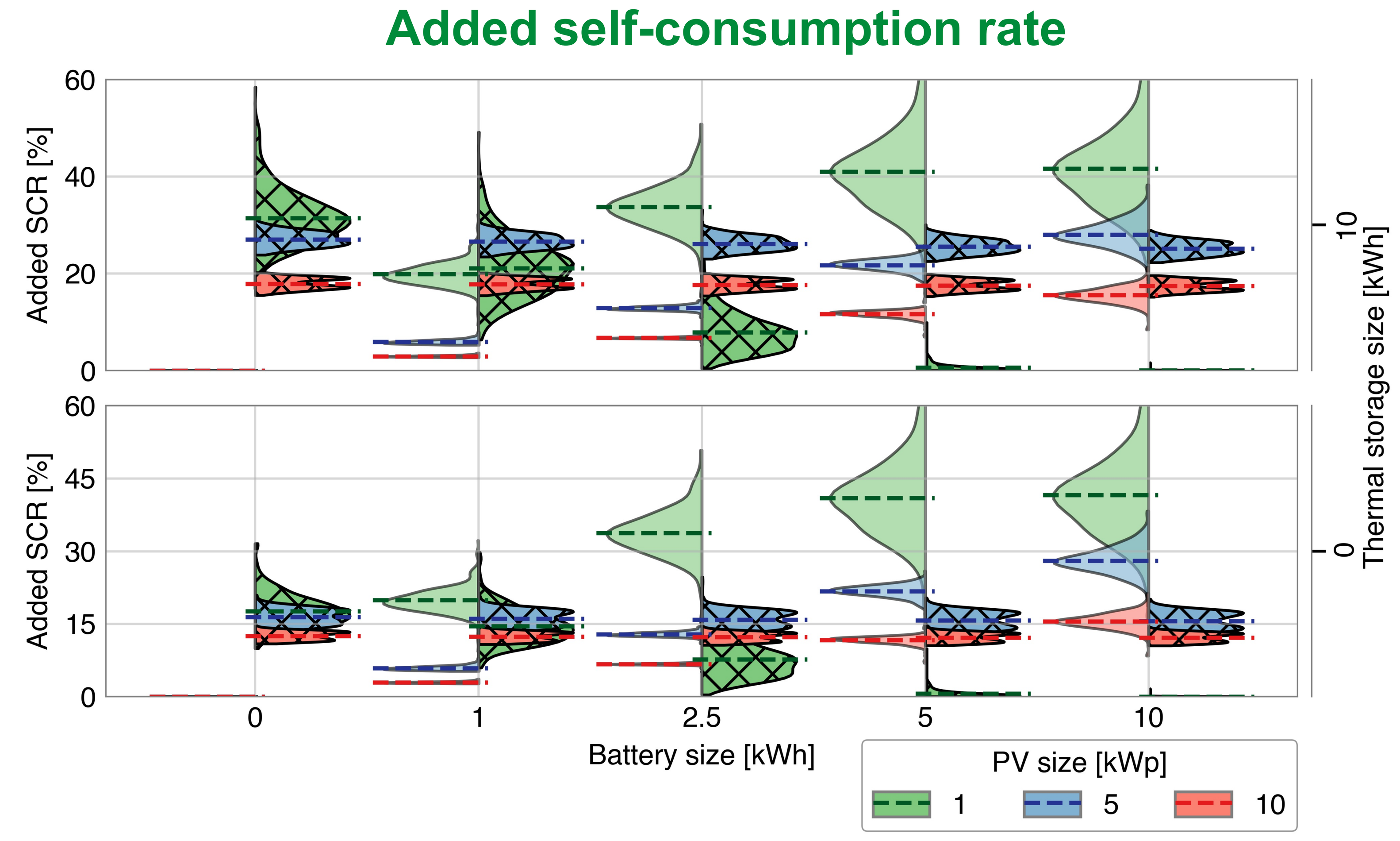
Self-consumption rate



SCR distributions from PV systems combined with five battery storage capacities (horizontal axis) and two thermal storage capacities (top & bottom). **SCR** of the **BPA** algorithm are shown on the left violins and **TPA** algorithm on the right violins (marked).

When no thermal storage is available, the electricity stored within battery can be used for the heat pump. However the heat stored cannot be transformed back to electricity. Consequently, the **BPA** algorithm results in a higher self-consumption.

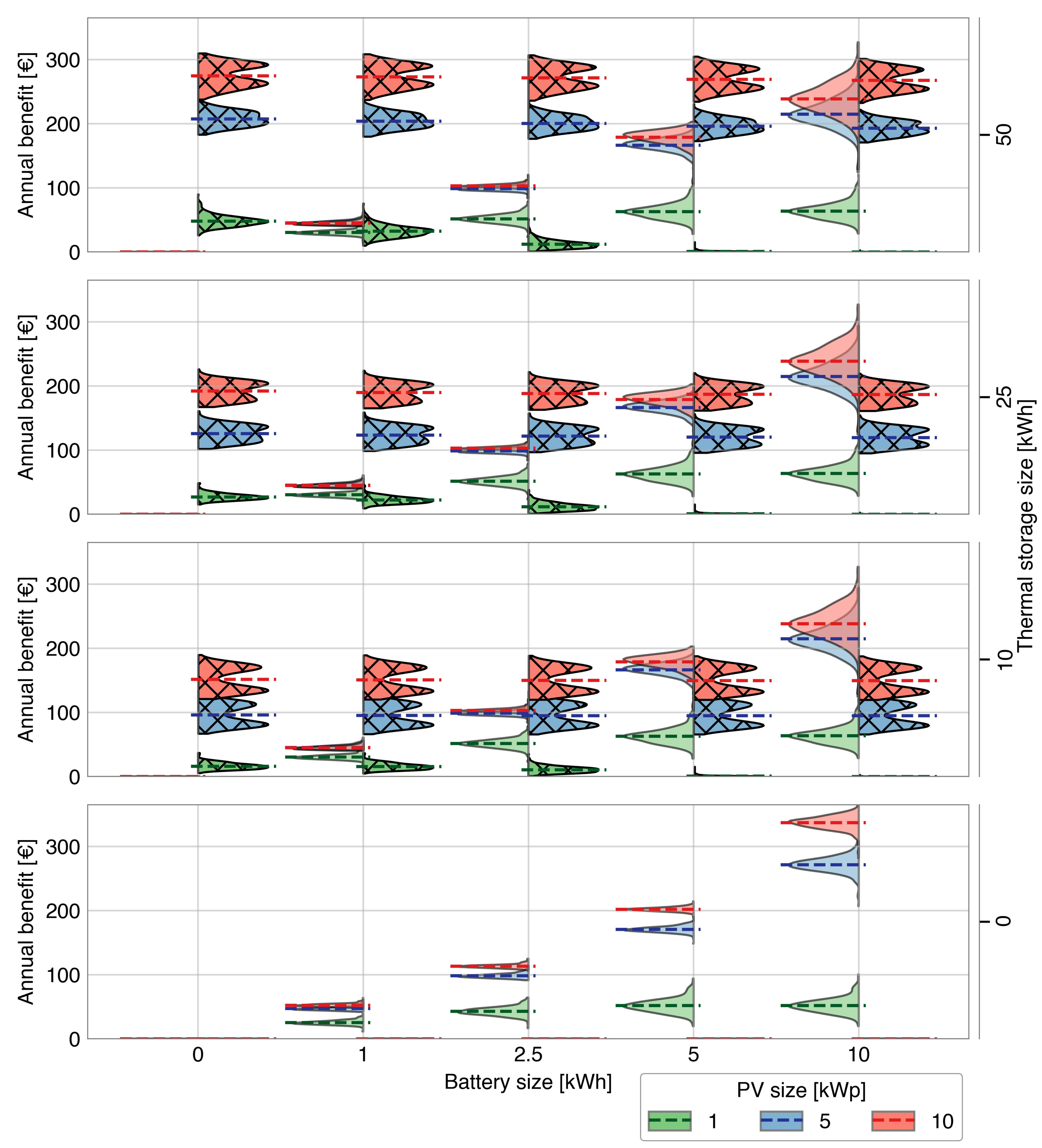
Added self-consumption rate



Distributions of added **SCR** due to the battery storage (left side) and heat storage (right side) using the **BPA** algorithm. Impact of electricity storage is larger than thermal storage because less heat is required in months with high PV energy production..

Consequently, the thermal storage is fully charged and surplus of PV electricity is mainly stored in the battery. Thus the added **SCR** due to thermal storage decreases for a small PV system of 1 kWp with larger battery.

Annual benefits



Distributions of annual benefits due to battery storage (left violin) and due to thermal storage (right violin) using the **BPA** algorithm. Benefits were found using an electricity consumption tariff of €0.23/kWh and feed-in tariff of €0.10/kWh.

Annual financial benefits for a 1 kWp PV system are around €40, for a battery size of 5 kWh without thermal storage. This benefit is similar for a thermal storage capacity of 50 kWh and no battery storage. Yet, a combination of these options results in an annual benefit of around €65. Thus a combination of systems decreases the benefits for each kWh of individual storage technology.

Furthermore, annual financial benefits of the thermal storage are decreasing with and increasing battery size coupled with a 1 kWp PV system. This is caused by the prioritization of battery storage over thermal storage in the **BPA** algorithm. The 5 and 10 kWp PV systems produce higher shares of excess electricity which can be stored as thermal energy. Hence the total bought electricity is reduced and annual benefits increased.

[1] Andrews, R.W.; Stein, J.S.; Hansen, C.; Riley, D., "Introduction to the open source PV LIB for python Photovoltaic system modelling package," in Photovoltaic Specialist Conference (PVSC), 2014 IEEE 40th , pp 170-174

[2] G. Litjens, W. van Sark, and E. Worrell, "On the influence of electricity demand patterns, battery storage and PV system design on PV self-consumption and grid interaction," in 2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC), June 2016, pp. 2021– 2024.