



Operational experience from battery systems in PV Power Plants

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- **Introduction** – Battery Energy Storage System (BESS) use-cases
- **Case study #1** – RISE's Research Villa
 - Effect of battery storage and use-case on the system's self-consumption (SC)
- **Case study #2** – RISE's PV and BESS field
 - Empirical evaluation of SC and self-sufficiency (SS) w.r.t. PV sizing
 - Evaluation of seasonal variation in SC and SS, and the effect of adding BESS
- **Take-away's**

Introduction – BESS use-cases



Table 8: Functional classification of PV + BESS use cases.

	Name of use case	Function	Typical duty cycle
Energy management	Peak shaving and time shifting	Avoid/reduce clipping losses Avoid/reduce curtailment losses Increase utilization of infrastructure Reduce energy costs of operation	Daily/few deep cycles
	Self-consumption and self-sufficiency	Maximize share of self-consumed PV power	Daily/few deep cycles
Market operations	Spot market	Energy arbitrage	Frequent cycles of varying depth
	Capacity market	Profitability based on ability to supply firm power (W) in accordance with contract (PPA)	Daily/few deep cycles with frequent smaller corrections
	Day ahead and intra-day bidding	Reduction of production forecast uncertainty Reduction/avoidance of imbalance fee	Variable
Resilience	End user energy resilience	Energy resilience for end users Power back-up Black start capabilities	Few deep cycles
Grid services	Capacity firming and smoothing	Capacity firming Smoothing Ramp rate control	Frequent shallow cycles (firming, smoothing), few deeper cycles (ramp rate control)
	Ancillary services	Provision of frequency reserves Provision of voltage support	Frequent fast and potentially deep cycles
Off-grid	Off-grid PV and appliances	Off-grid PV systems PV appliances	Large variation

Source: Stensrud Marstein, E., Messner, C. (2026). Stensrud Marstein, E., Köntges, M., Jahn, U. (Eds.), *Assessing the Reliability of Battery Systems in Solar Power Plants in Operation* (Report No. T13-35:2026). IEA PVPS Task 13. DOI: 10.69766/EIRM192

Case study #1 – RISE's Research Villa



- **RISE's research villa**

- Single-family residential building in Sweden
- Electric heating (ground-source heat pump)
- Annual electricity demand: 6,354 kWh
- PV system: 3.7 kWp; 3,113 kWh/a
- Yearly 15-minute data; consumption and production



- **Three dispatch algorithms for battery operation**

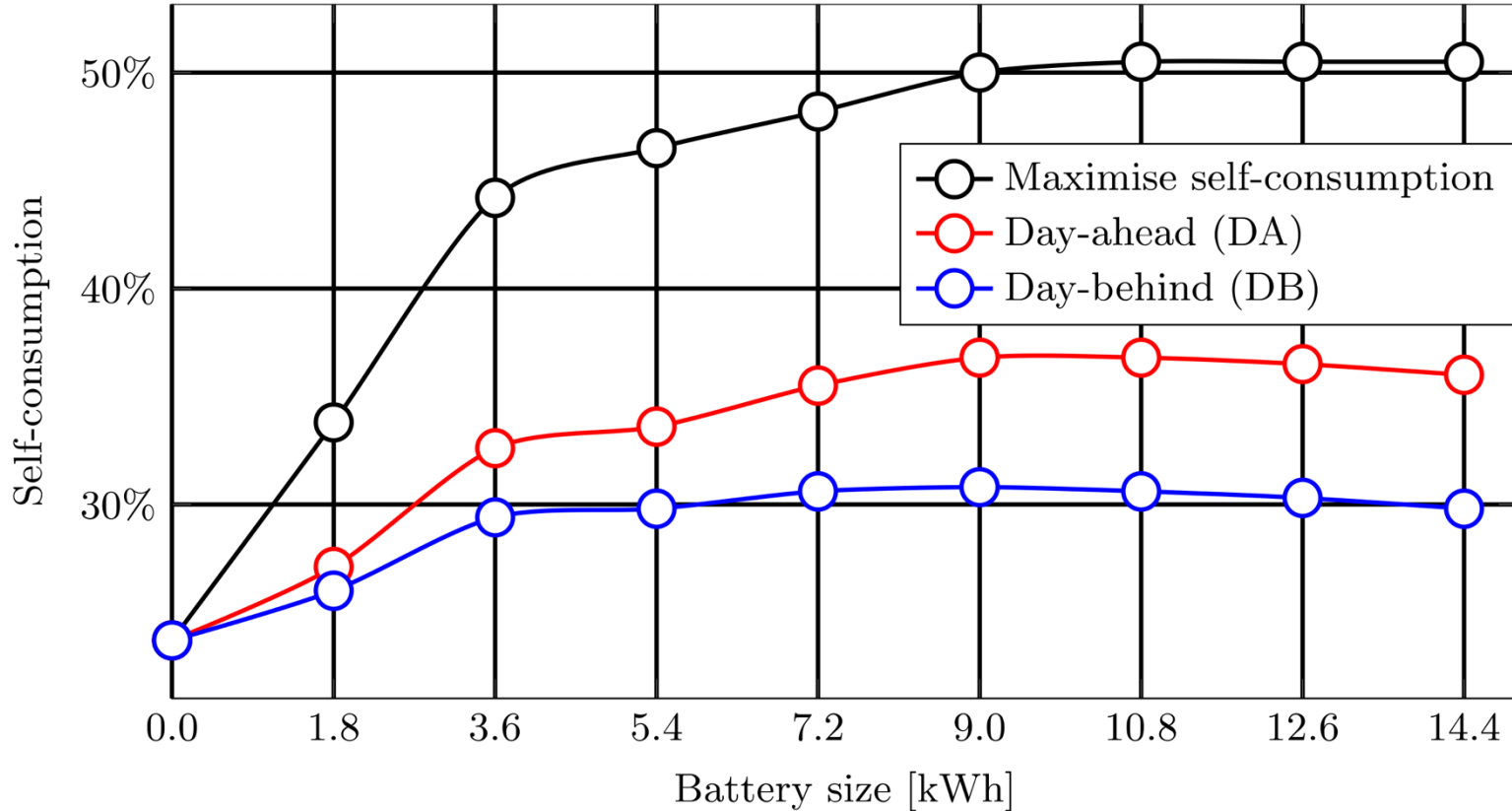
- Maximise self-consumption

- Day-ahead (DA)

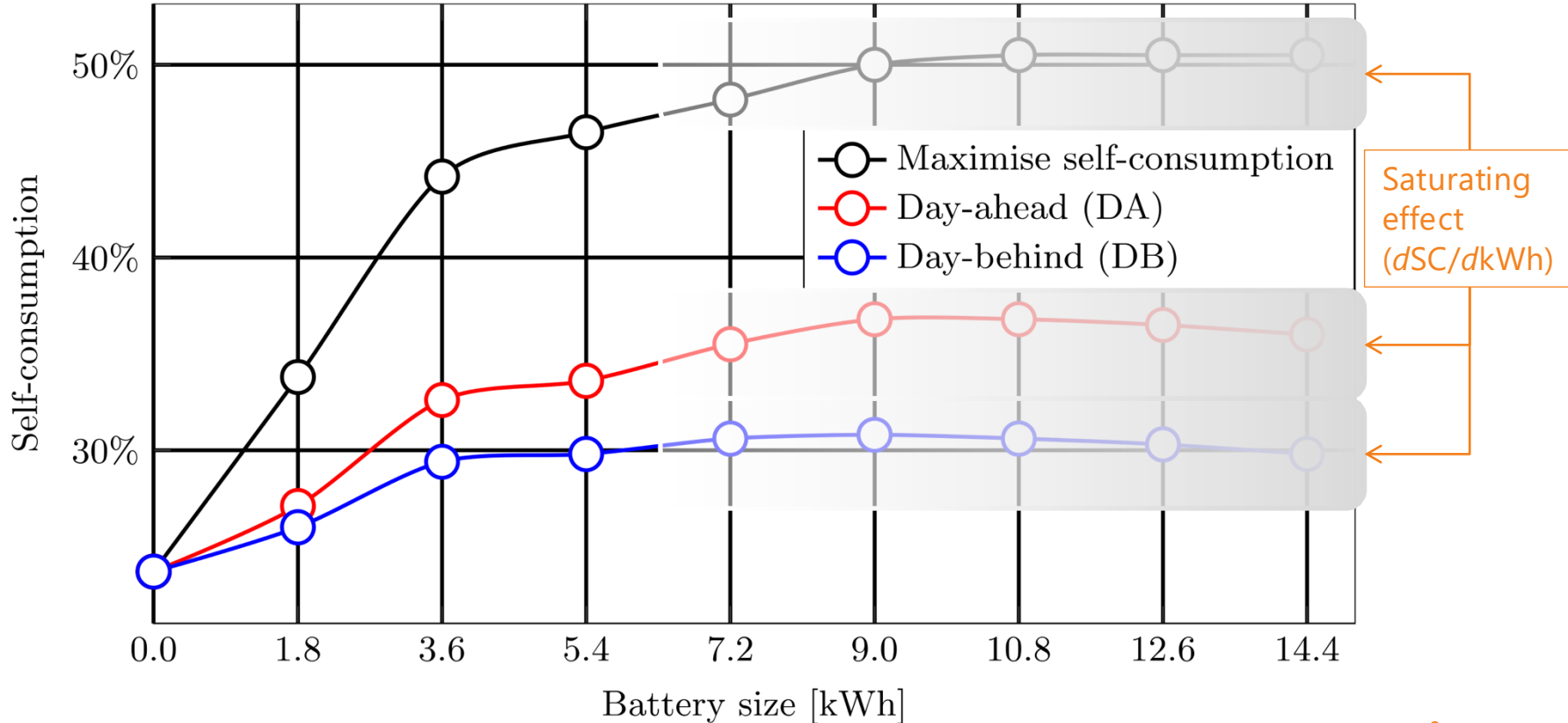
- Day-behind (DB)

} Peak power-shaving objective

Self-consumption vs. battery size



Self-consumption vs. battery size



Case study #2 – RISE's PV and BESS field



- **PV and BESS field**
- Nine PV arrays in Borås, Sweden



Case study #2 – RISE's PV and BESS field



- **PV and BESS field**

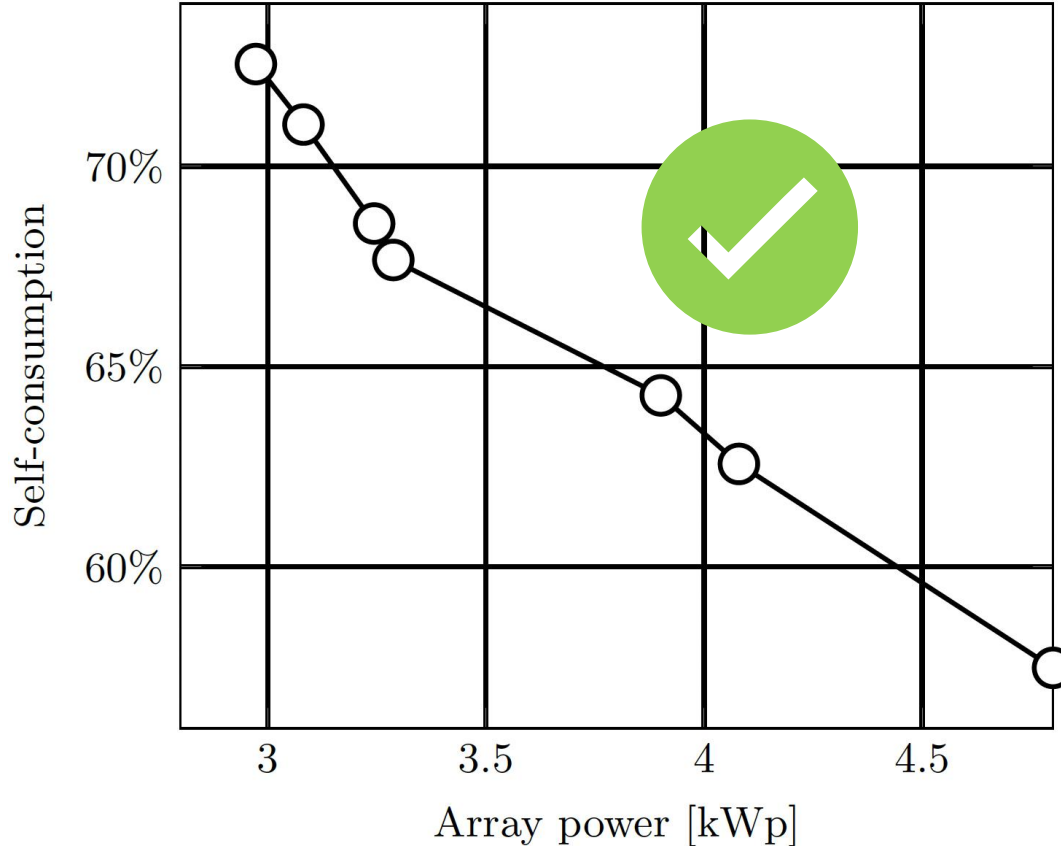
- Nine PV arrays in Borås, Sweden
 - c-Si, CIGS and CdTe
 - 3.0–6.2 kWp
 - BAPV and BIPV systems
- Residential load – 16.9 MWh/a; 6.0 kW peak
- One (1) battery storage system – 5.7 kWh/4.6 kW

NB! BESS operation to maximize self-consumption throughout the year

- **Evaluation metrics**

- Self-consumption and self-sufficiency vs. PV array power

Case study #2 – RISE's PV and BESS field



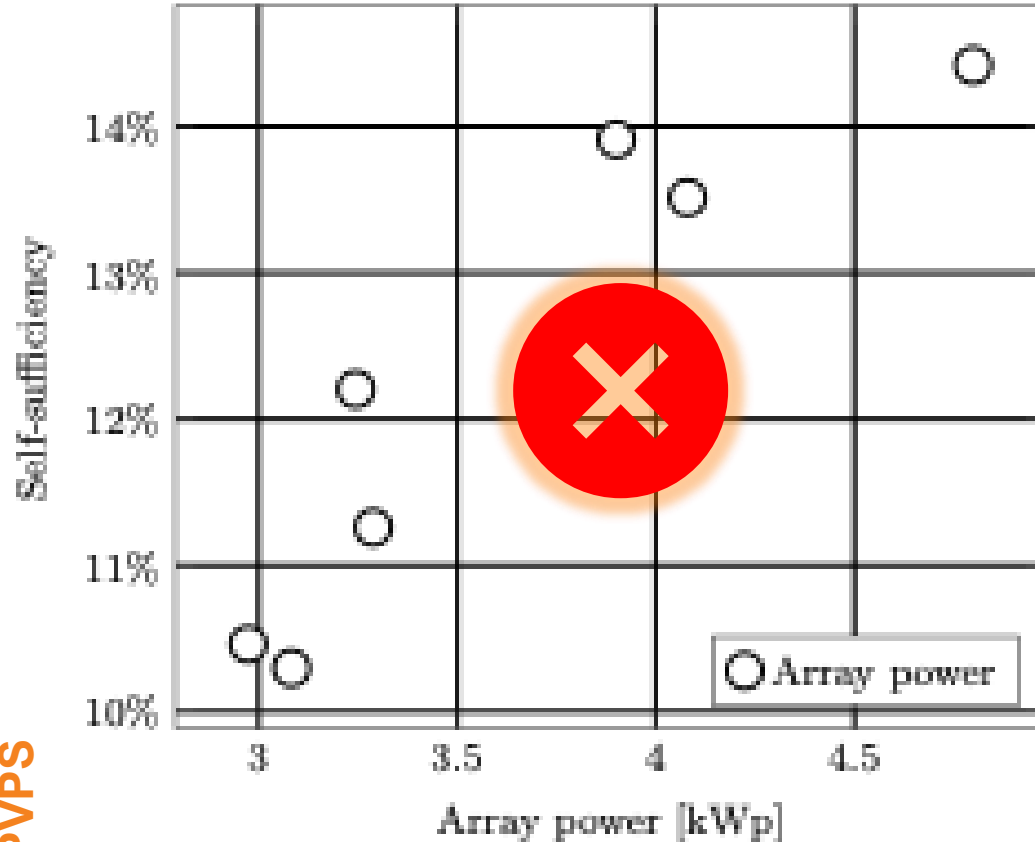
- Negative correlation: **self-consumption v PV array power**^[1]: confirmed!

[1] R. Luthander, J. Widén, D. Nilsson, and J. Palm, "Photovoltaic self-consumption in buildings: A review," *Applied energy*, vol. 142, pp. 80–94, 2015.

Case study #2 – RISE's PV and BESS field



PVPS



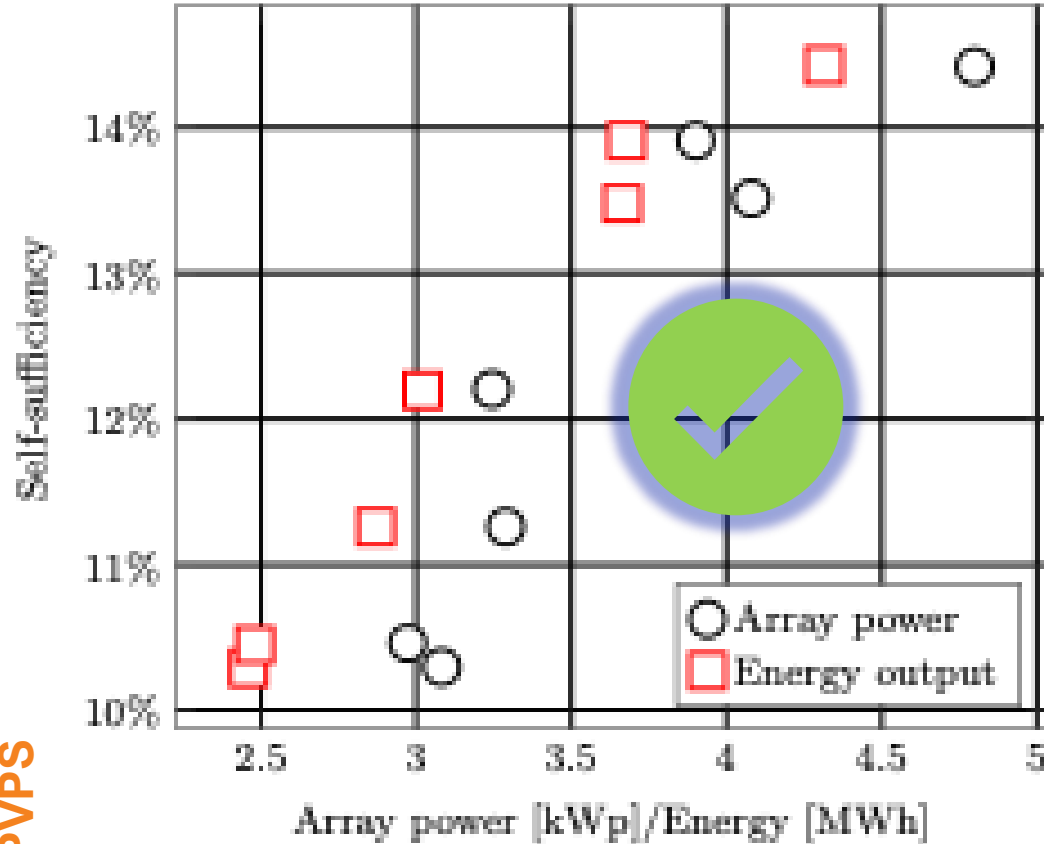
- Positive correlation: **self-sufficiency v PV array power**^[1]: not confirmed!

[1] R. Luthander, J. Widén, D. Nilsson, and J. Palm, "Photovoltaic self-consumption in buildings: A review," *Applied energy*, vol. 142, pp. 80–94, 2015.

Case study #2 – RISE's PV and BESS field



PVPS



- Positive correlation: **self-sufficiency** v **PV yield**: proven!
- PV yield (Energy output) better captures the system's performance, having differences in **cell technology** and roof integration (**BIPV/BAPV**).

Case study #2 – RISE's PV and BESS field



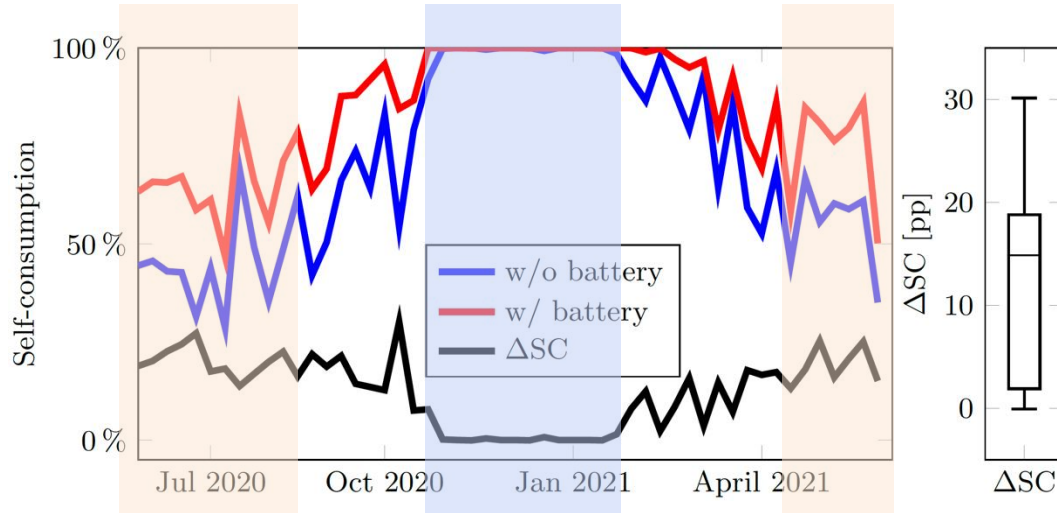
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- **Evaluation metrics**

- Self-consumption and self-sufficiency vs. PV array power
- Self-consumption and self-sufficiency w/ and w/o BESS

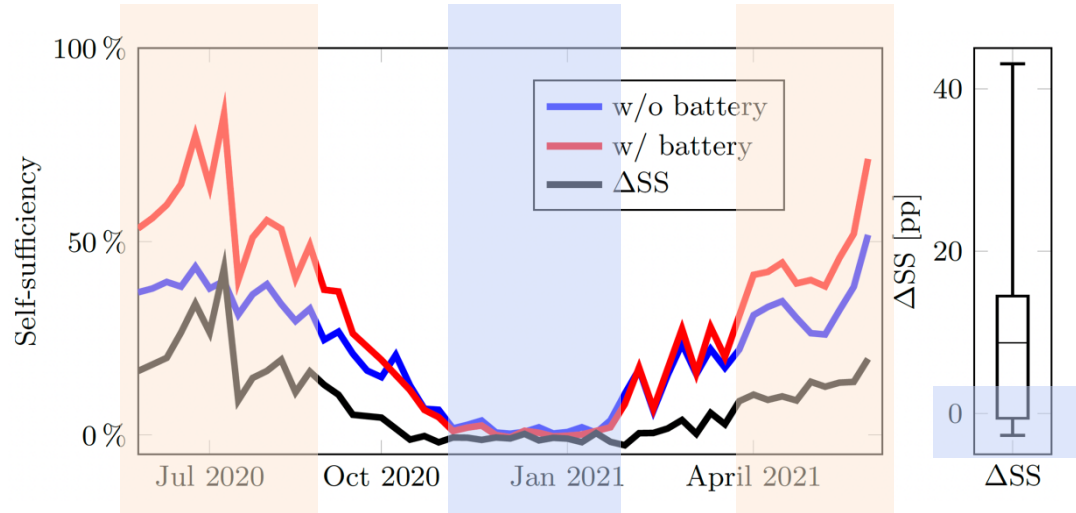
Case study #2 – RISE's PV and BESS field



- **Self-consumption (SC)**
w/ and **w/o** battery storage during one year's operation
- **Boxplot:** gain in SC

- Most significant gains in the summer (**left** and **right**)
- No addition during the winter (middle)
- SC gains up to 30 percentage points!

Case study #2 – RISE's PV and BESS field



- **Self-sufficiency (SS)**
w/ and **w/o** battery storage from one year's operation
- **Boxplot:** gain in SS

- Most significant gains in the summer (**left** and **right**)
- Negative effect from the battery during the winter (middle)
- SS gains above 40 percentage points!



- Experiences from field measurements of PV + BESS systems in a Nordic Climate
- Evaluations of systems' **self-consumption and self-sufficiency**
- Proven correlation between **self-sufficiency and PV yield!**
- *Confirmed correlation between **self-consumption and PV array size***
- A BESS add **gains in self-consumption and self-sufficiency**
 - **Saturation effect** noticeable; system sizing important!
 - **Seasonal dependency** on gains!
- Single-objective operation is not suitable for Nordic climates, underscoring the need to **utilise the full “Swiss army knife”!**

Thank you!

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