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Reza Fachrizal

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SOLVE

How can PV systems, alongside wind power and electric vehicle charging, be optimized to enhance the performance of urban energy systems?

Reza Fachrizal

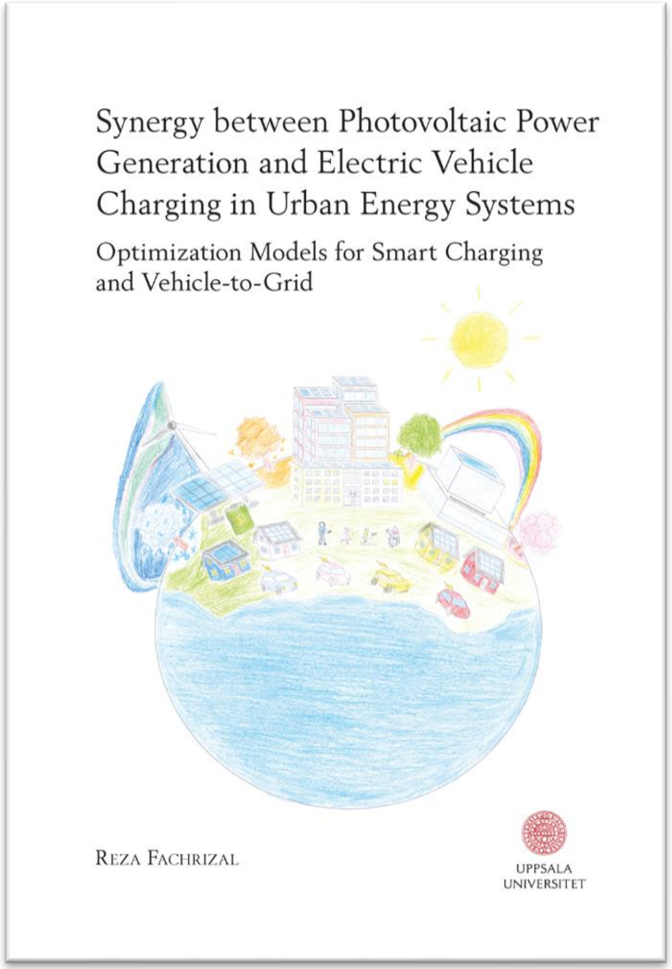
Introduction

Ph.D degree: in Engineering Science, from Uppsala University

PhD thesis: Solar energy and electric vehicle charging in urban energy systems

Research interests: Renewable energy, multi-energy systems, transport electrification, energy flexibility

Current activity: Postdoctoral researcher at Future Energy Center, Mälardalen University, Västerås



Outline

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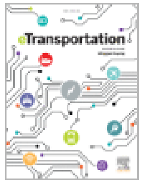

Urban-scale energy matching optimization with smart EV charging and V2G in a net-zero energy city powered by wind and solar energy

Reza Fachrizal [a] [1], Kun Qian [b] [1], Oskar Lindberg [a], Mahmoud Shepero [a], Rebecca Adam [b], Joakim Widén [a], Joakim Munkhammar [a]

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- Urban energy systems
- Energy matching
- Optimization
- Wind power
- Solar power
- Electric vehicle charging
- Vehicle-to-grid

https://doi.org/10.1016/j.apenergy.2021.118139

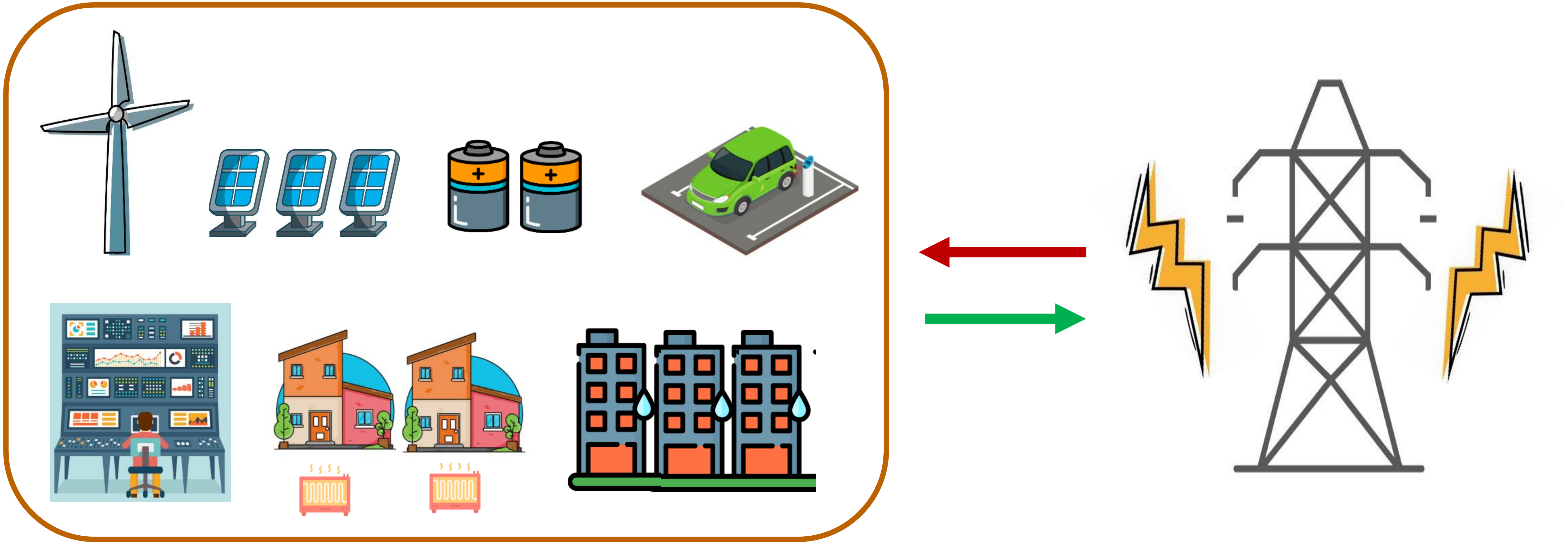
Outline

- Urban energy systems and their boundary.
- Renewable electricity utilization: self-consumption, self-sufficiency, the balance.
- Urban transport electrification: Opportunistic charging, smart charging, vehicle-to-grid.
- Optimal sizing of solar-wind ratio in a Swedish city case study.
- Vehicle-to-grid compared to stationary battery in urban energy systems.

Urban energy systems:
Grid and local energy system interaction

Local energy system

The main grid

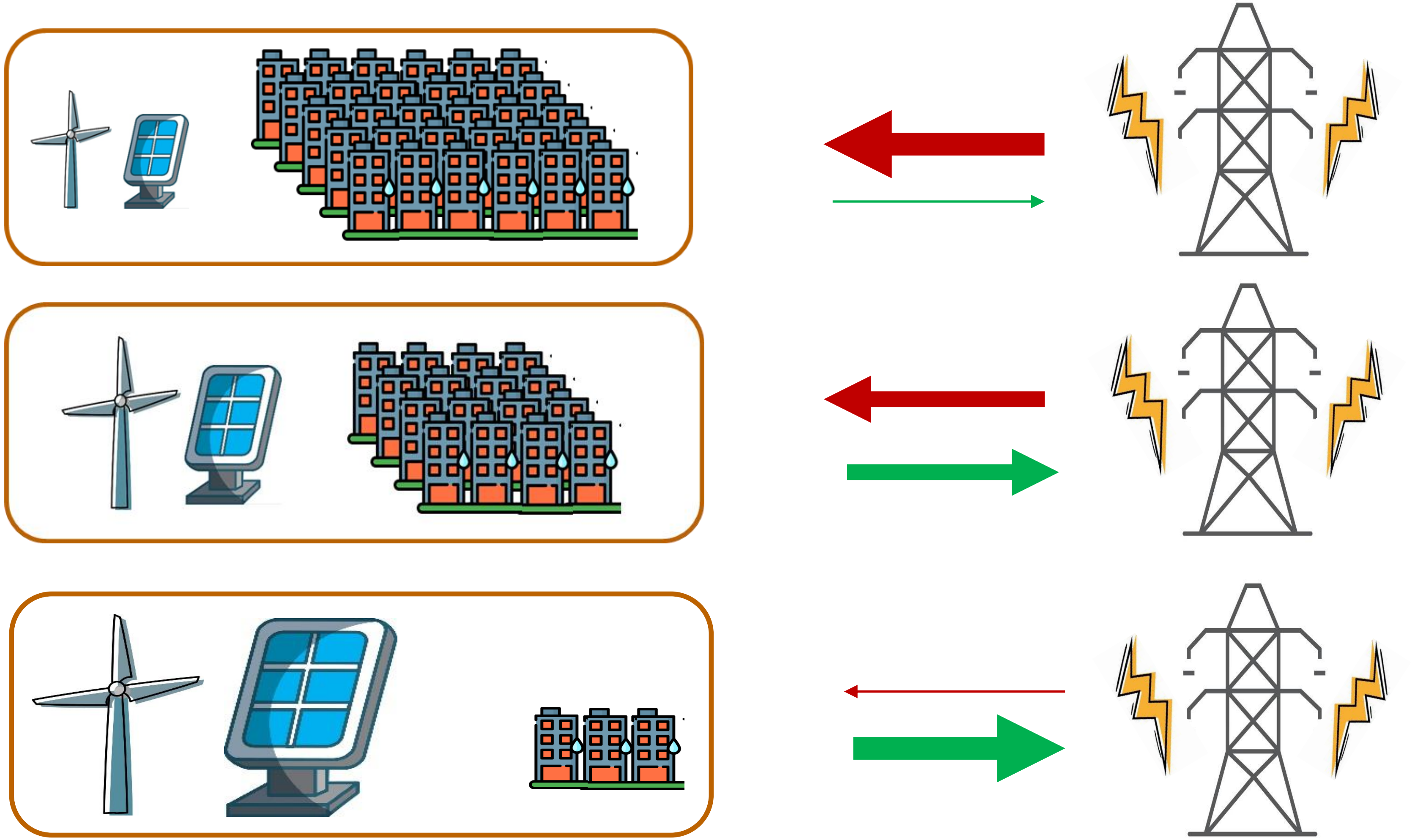


Urban energy systems: producer, consumer and net-zero

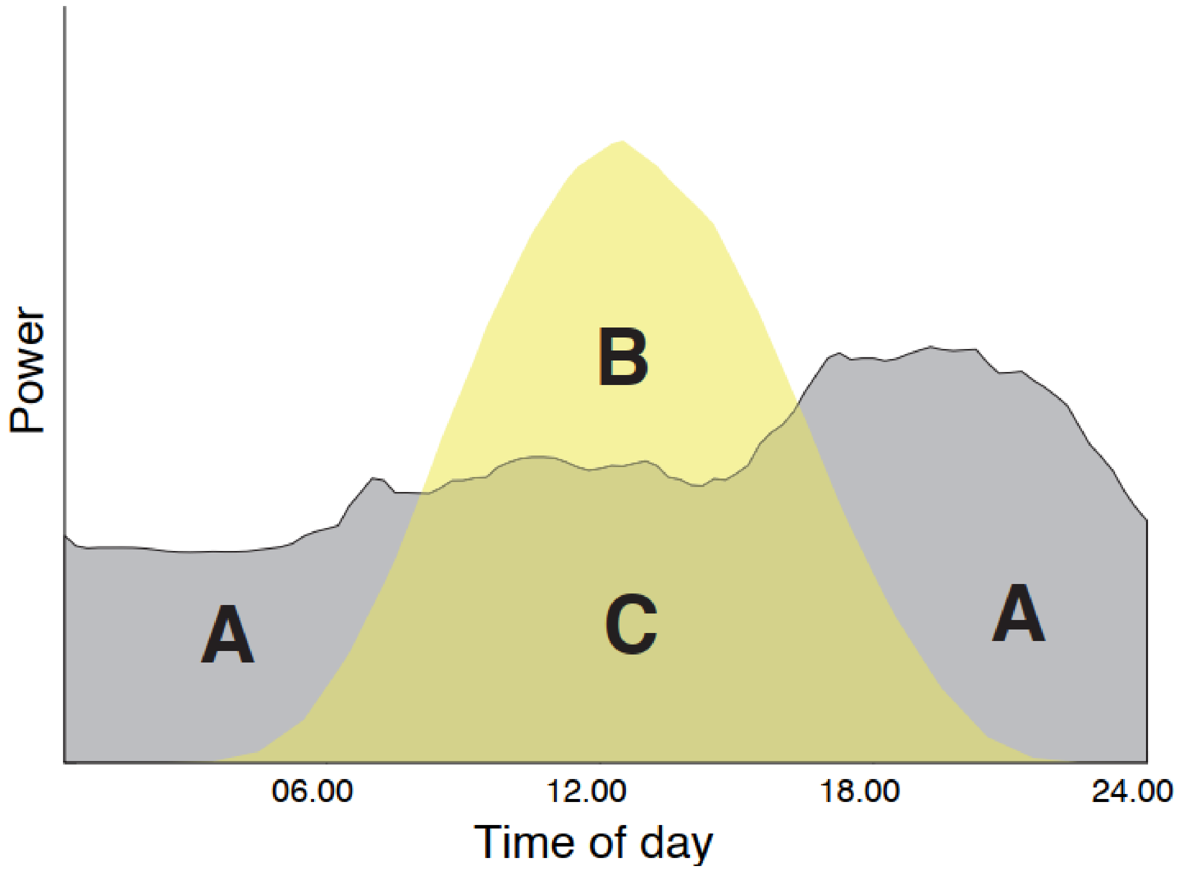
Net consumer

Net-zero energy

Net producer
(Positive energy district)



Renewable energy utilization:
Local generation self-consumption (SC)
Local energy system self-sufficiency (SS)



Based on the illustration

Load = (**A** + **C**)
DG electricity = (**B** + **C**)
Self-consumed electricity = **C**

$$SC = \frac{C}{B+C} \qquad SS = \frac{C}{A+C}$$

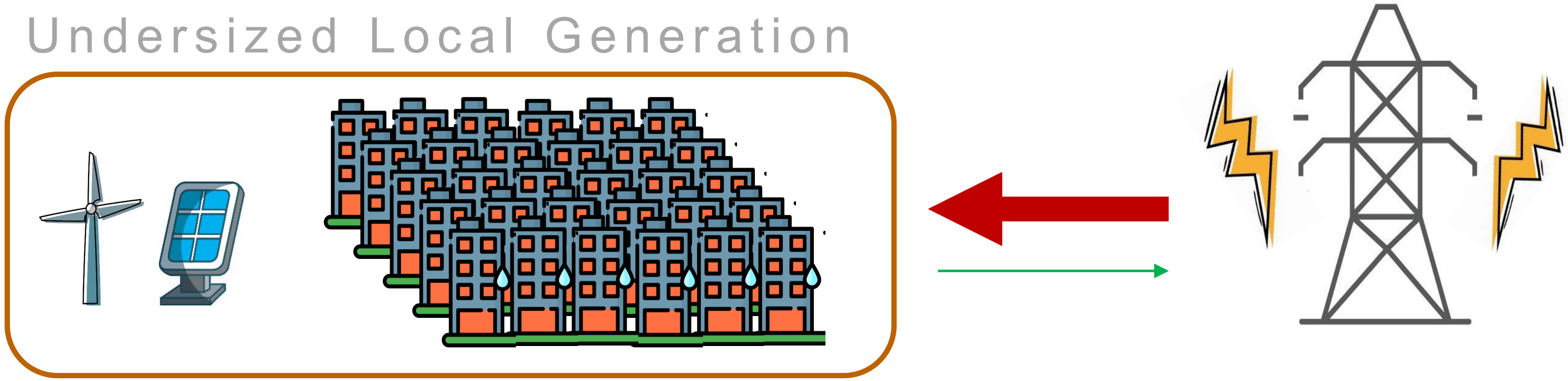
Formal math formulation

$$M_t = min(P_{P,t}, P_{L,t})$$

$$\phi_{SC} = \frac{\int M_t dt}{\int P_{P,t} dt} \qquad \phi_{SS} = \frac{\int M_t dt}{\int P_{L,t} dt}$$

M_t = instantaneous self-consumed electricity at time t
$P_{P,t}$ = instantaneous power production electricity at time t
$P_{L,t}$ = instantaneous power load electricity at time t

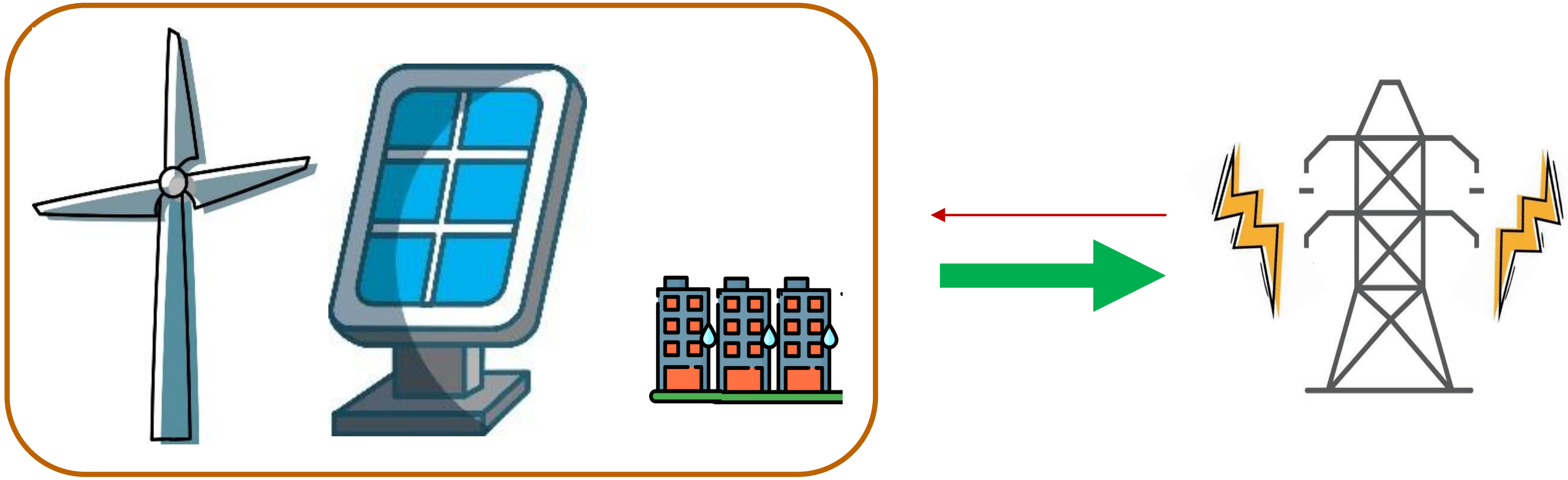
Undersized Local Generation



High SC
Low SS

The district relies on the grid in **fulfilling their energy demands**

Oversized Local Generation



Low SC
High SS

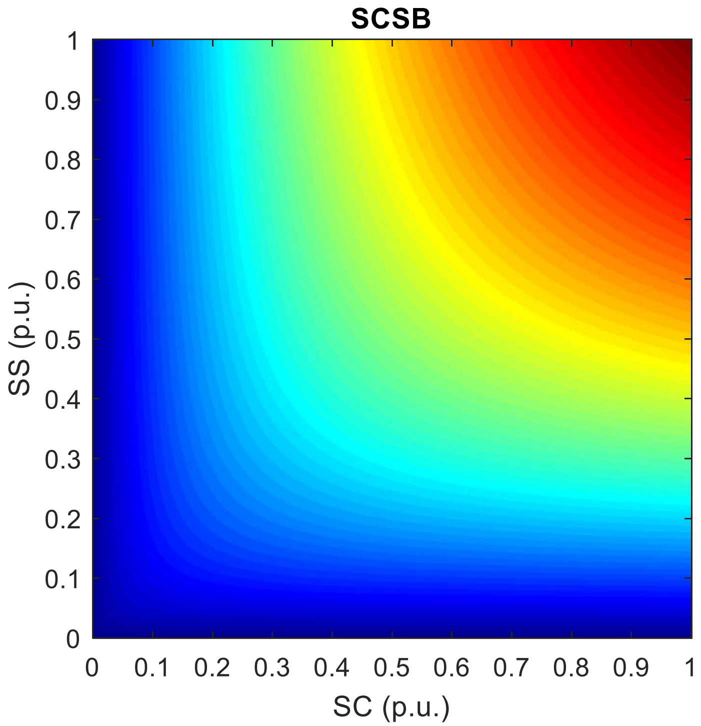
The district relies on the grid in **handling the overgeneration problems** or otherwise needs to **curtail most of the energy production**

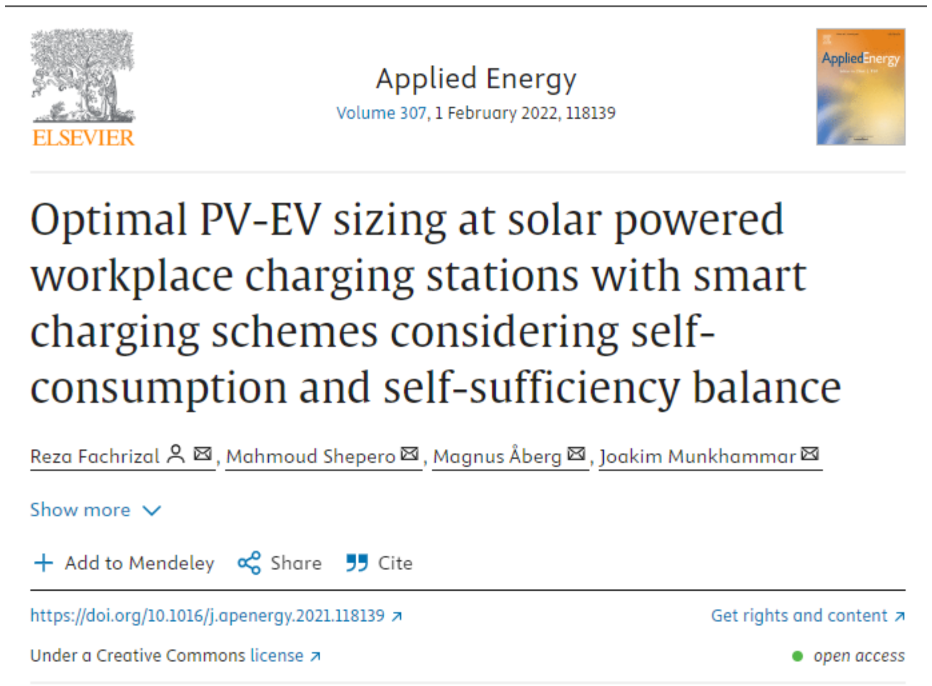
*No storage nor load shifting is deployed

The balance between self-consumption and self-sufficiency

Using harmonic mean formulation

$$\mathrm{SCSB} = \frac{2 \times \mathrm{SC} \times \mathrm{SS}}{\mathrm{SC} + \mathrm{SS}}$$





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Applied Energy

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Optimal PV-EV sizing at solar powered workplace charging stations with smart charging schemes considering self-consumption and self-sufficiency balance

Reza Fachrizal, Mahmoud Shepero, Magnus Åberg, Joakim Munkhammar

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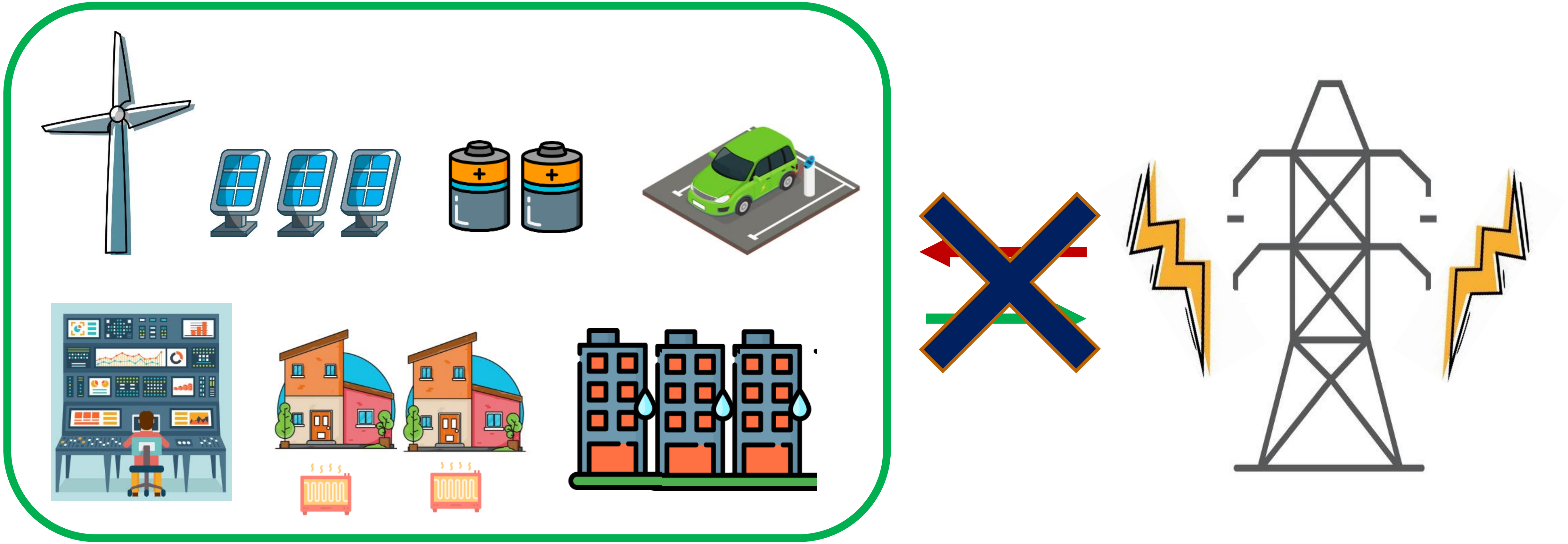
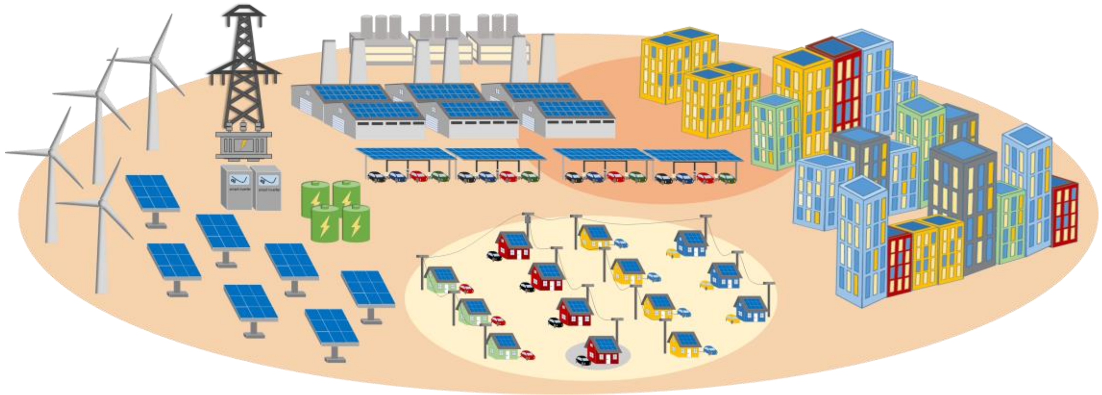
What does SCSB of 1 means?



SCSB = 1 means that the district is both energy and power fully-independent
+ with 0 kWh curtailed generation

Urban electric vehicle charging

- Opportunistic/uncontrolled charging: EVs are charged as soon as they arrive at the charging destination.
- Smart Charging: EVs are charged at the charging destination with the ability to adjust unidirectional charging rate and time to enhance the system's performance. I.e., only charging is allowed.
- Vehicle-to-grid: EVs are charged at the charging destination with the ability to adjust bidirectional charging rate and time to enhance the system's performance. I.e., both charging and discharging are allowed.



Urban scale load profile including solar and wind generation

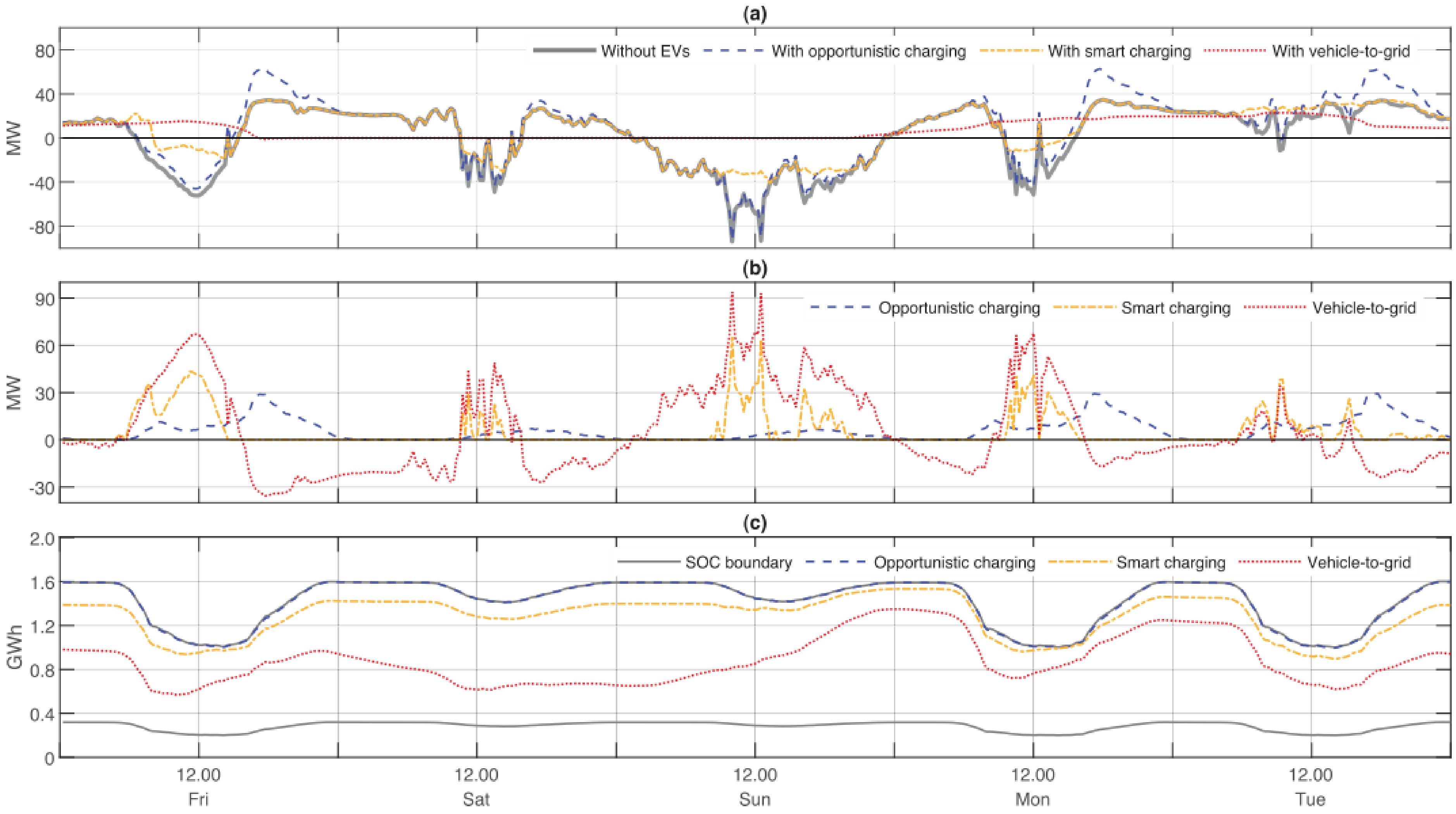


Fig. 13. (a) Net load (load minus generation), (b) net charging power (positive values represent charging, and negative values represent discharging) and (c) aggregated SOC of EV batteries connected to the system, with different charging scenarios in five September days.

Optimal sizing

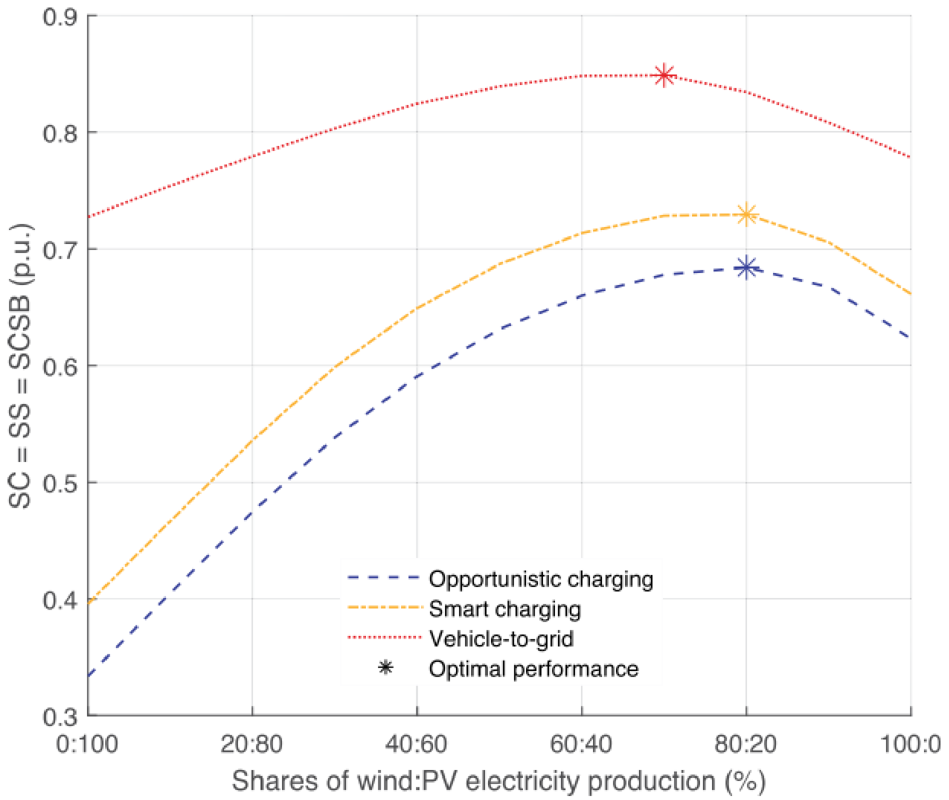


Fig. 9. City load matching performance with three different EV charging scenarios and different shares of wind-PV. Starred points indicate the optimal wind-PV shares in the respective charging scenarios.

In net-zero scenario, optimal wind-PV ratio

- 80% wind – 20% solar PV with opportunistic or unidirectional smart charging.
- 70% wind – 30% solar PV with bidirectional smart charging (vehicle-to-grid).

Daily average profile in different wind-PV ratio

Mälardalen University

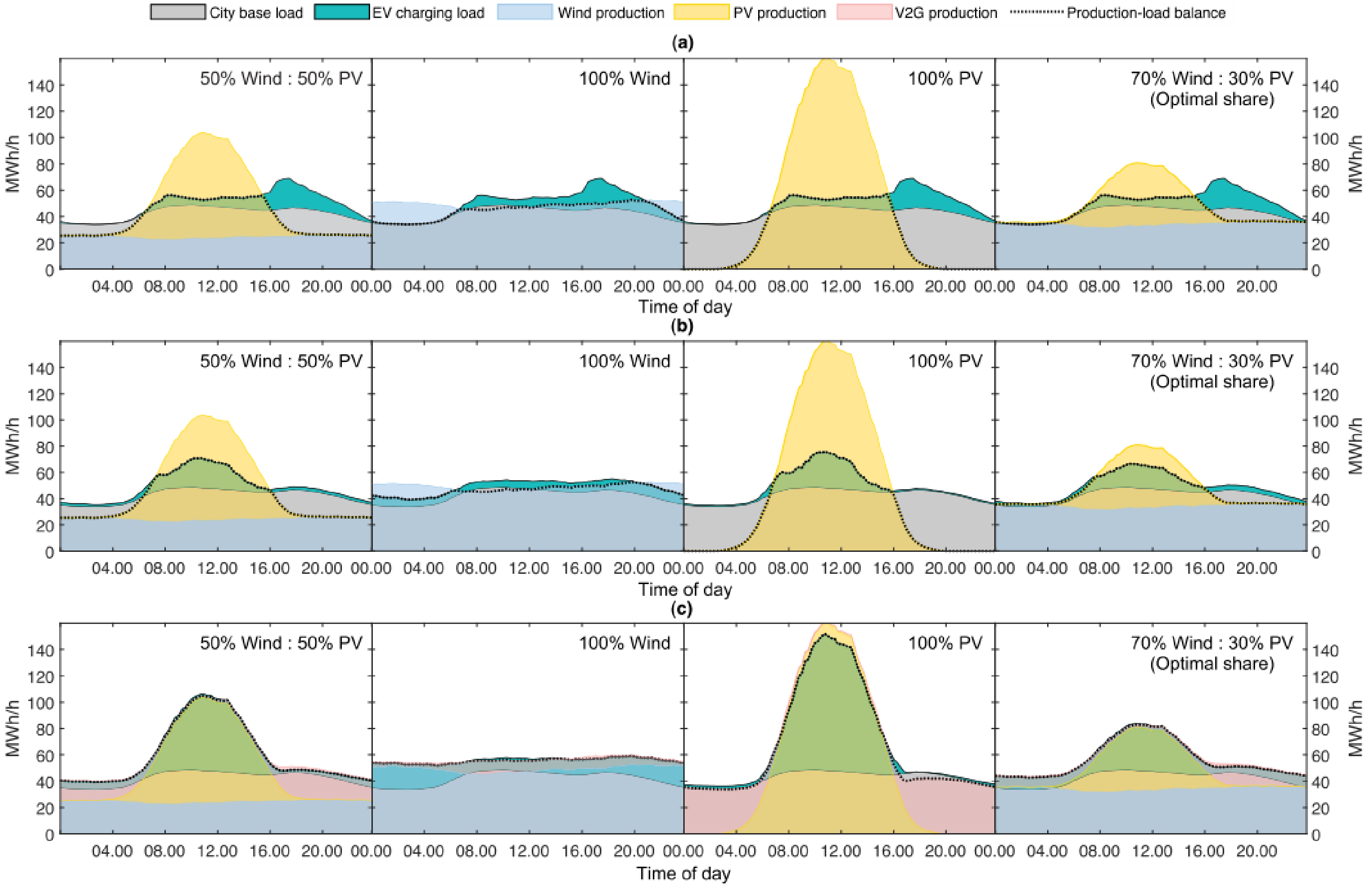


Fig. 11. Daily average of power production (transparent areas) and load (solid areas) in (a) uncontrolled charging, (b) smart charging and (c) V2G scenarios for four different wind-PV electricity production shares. The figure illustrates the diurnal correlation between production and load, and provides an approximation of the daily load matching performance at various wind-PV electricity shares.

Optimal sizing

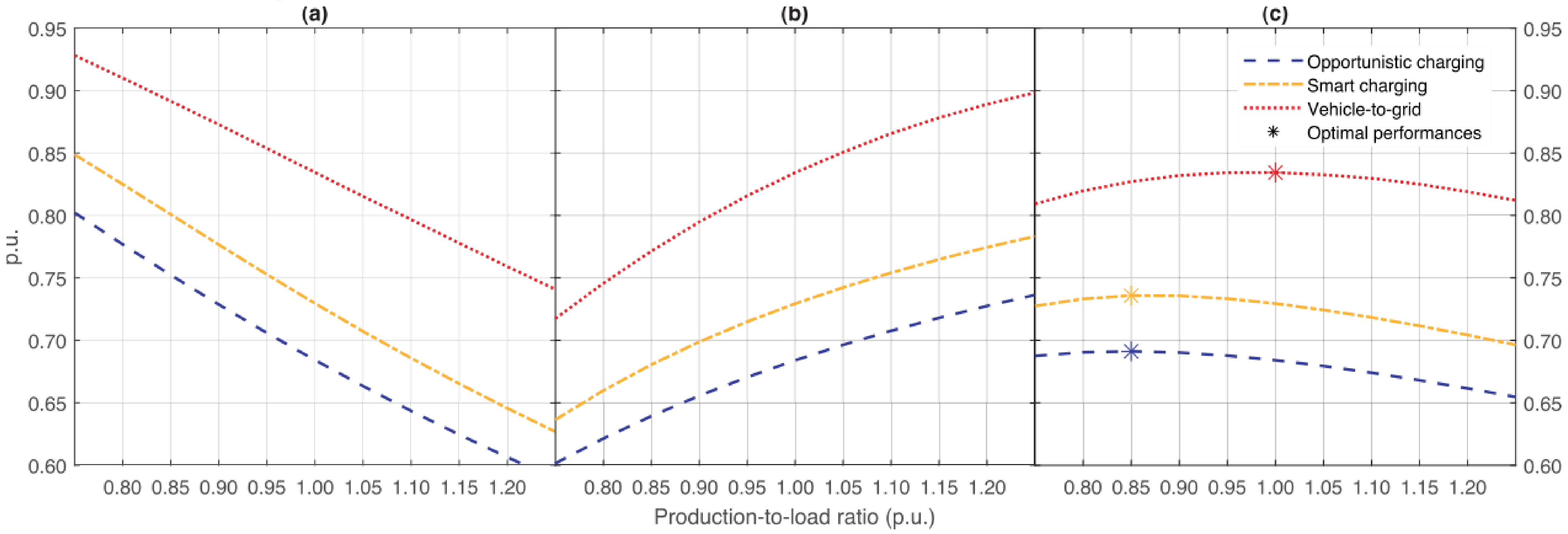


Fig. 12. Performance of (a) SC, (b) SS, and (c) SCSB in different P/L ratios and EV charging scenarios. Starred points indicate the optimal RES-load ratios in the respective charging scenarios.

Optimal production to load ratio

- 0.85 production-to-load ratio with opportunistic or unidirectional smart charging.
- 1.00 production-to-load ratio (net-zero energy) with bidirectional charging (vehicle-to-grid).

Vehicle-to-grid vs Stationary storage

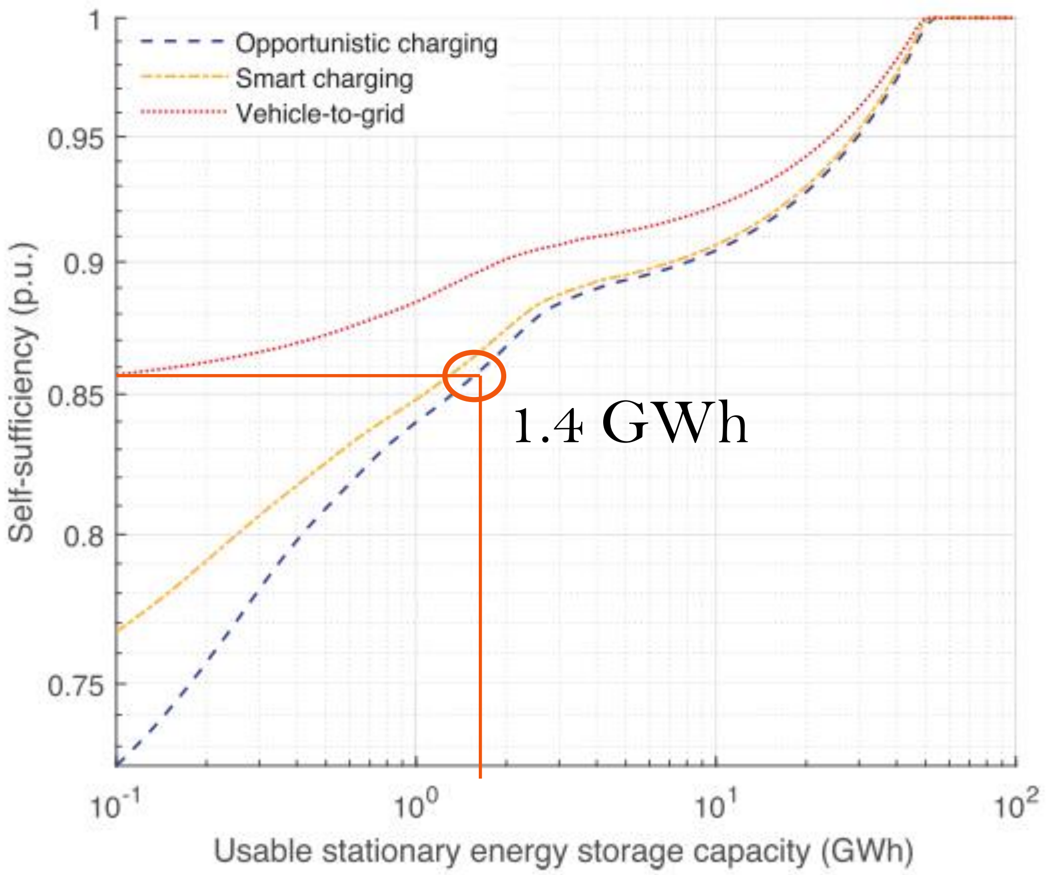


Fig. 17. City self-sufficiency with different stationary energy storage capacity in different EV charging scenarios in net-zero energy city.

2.4 GWh EV batteries with V2G schemes as intermittent energy storage is equal to a **1.4 GWh stationary storage** in terms of improving the urban-scale load matching performance.

Conclusion

- Among all scenarios of EV charging schemes, wind-PV electricity production shares, and generation-load ratios, the optimal load matching performance is achieved in a net-zero energy city with V2G deployment and **wind-PV electricity production** share of **70:30.**

- In the optimal net-zero energy city, the load matching performance is increased from **68%** in the opportunistic charging scenario to **73%** in the smart charging scenario and to **84%** in the V2G scenario.

- When EV flexibility is fully utilized, **2.4 GWh EV batteries with V2G** schemes as intermittent energy storage is equal to a **1.4 GWh stationary storage** in terms of improving the urban-scale load matching performance.

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Thank you!

reza.fachrizal@mdu.se

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