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Capacity tariffs and DSO-side downregulation as grid-relieving measures in future low voltage distribution systems

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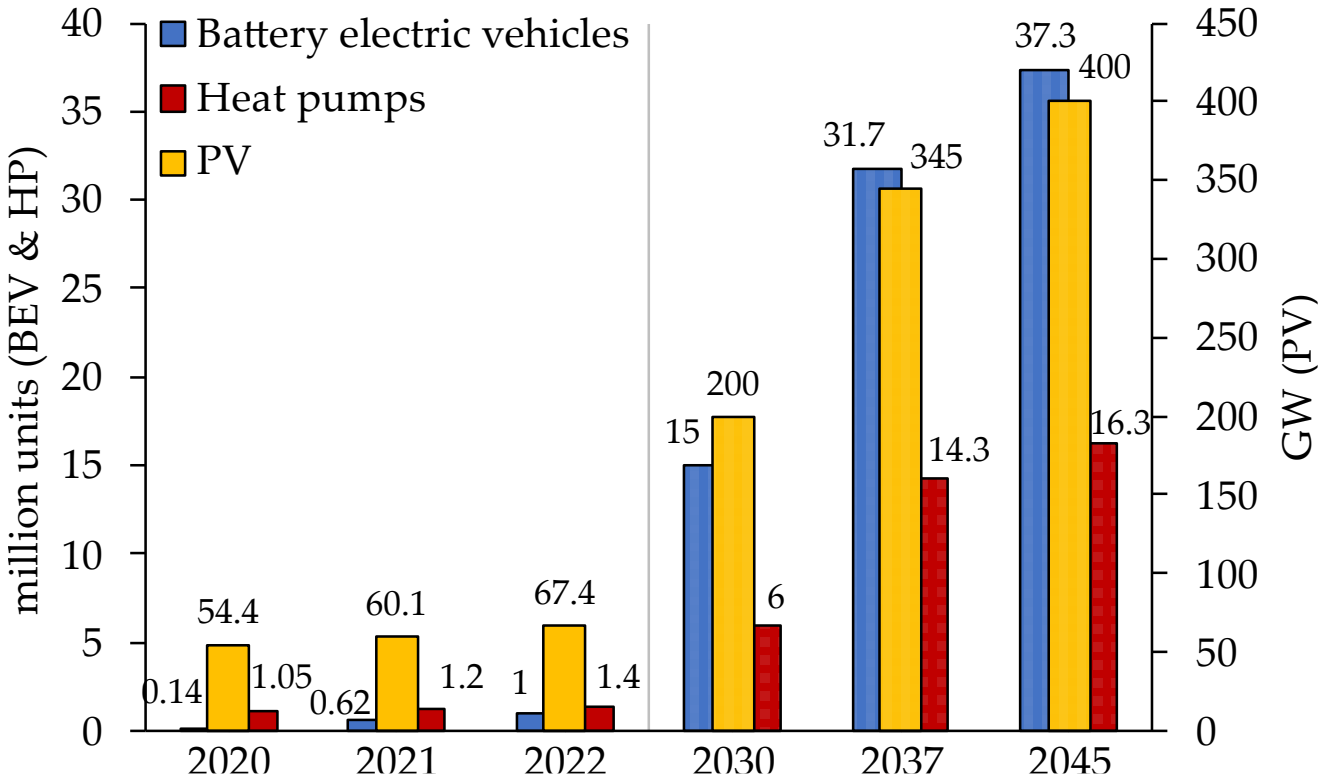
Future is (probably) electric in Germany

- Significant adoption targets for electric mobility, heat pumps and PV [1, 2, 3]
- Majority of these loads will come to low-voltage (LV) distribution grid level
- Significant transformation expected – **are the LV grids ready for this?**



[1] German Federal Network Agency. Genehmigung des Szenariorahmens 2023-2037/2045 (Approval of the scenario framework 2023-2037/2045). 7.2022.
[2] Jessica Bateman. Heat pump installation plans may overburden Germany's grid - energy industry. CleanEnergyWire. 2023.
[3] Kerstine Appunn. Next German government's key climate and energy plans in 2021 coalition agreement. CleanEnergyWire. 2021.

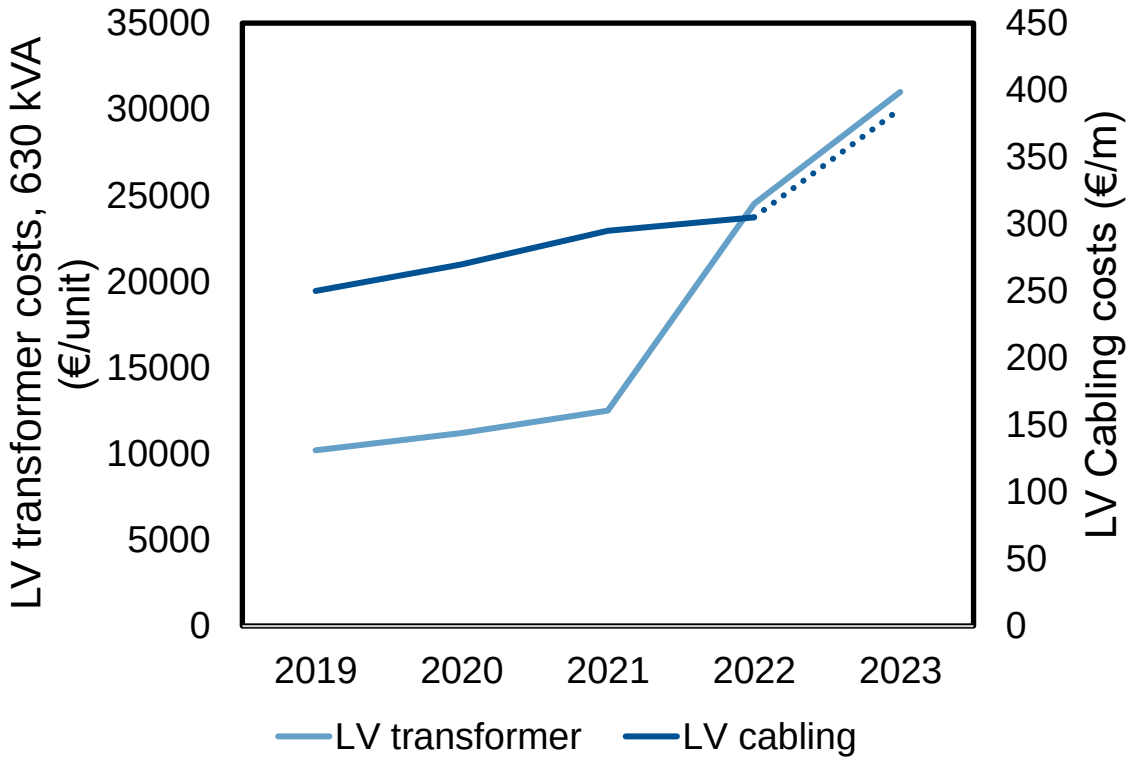
What are the options for the DSO?

Grid reinforcement looks like an obvious choice

- However, high demand and material costs are causing cost volatility, shortages, and long lead times

-> Comprehensive reinforcement by all DSOs (~900 in Germany) is infeasible, **so optimize the grids first!**

A German DSO‘s cost benchmark for LV grid components

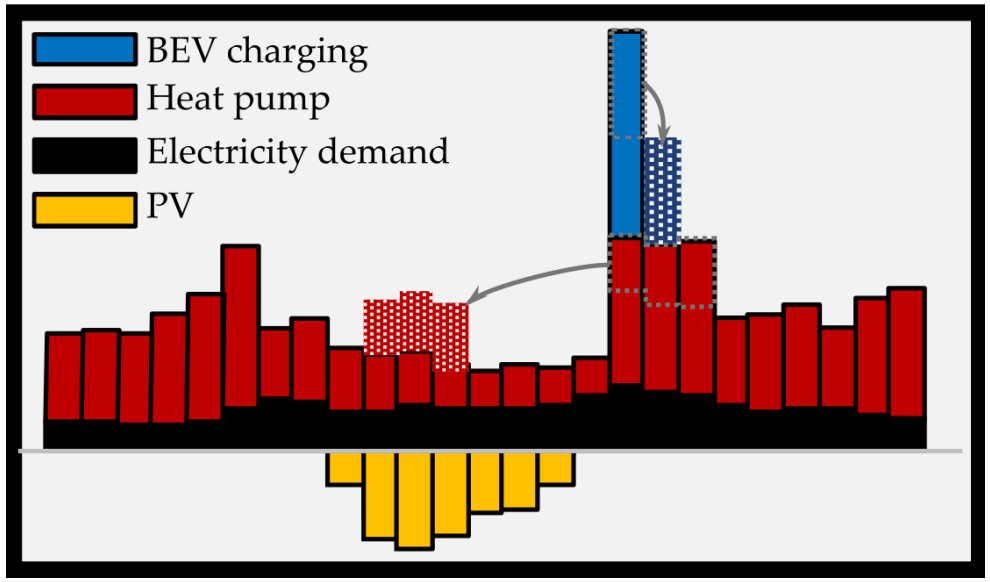


A German DSO‘s cost benchmark

How can the „prosumers“ assist the grid?

(Middle term) alternative: tapping into prosumers‘ flexibilities

- **Heat pumps** can „pre-heat“ buildings whenever electricity is cheaper (e.g. excess PV)
- **BEVs** can be charged over multiple hours instead of immediate charging



Incentives lacking under a fixed retail price regime!

Yet, things are changing:

Offering **time-variable network tariffs** obligatory by 2024 in Germany [4]

Offering **dynamic retail electricity tariffs** obligatory by 2025 in Germany [5],

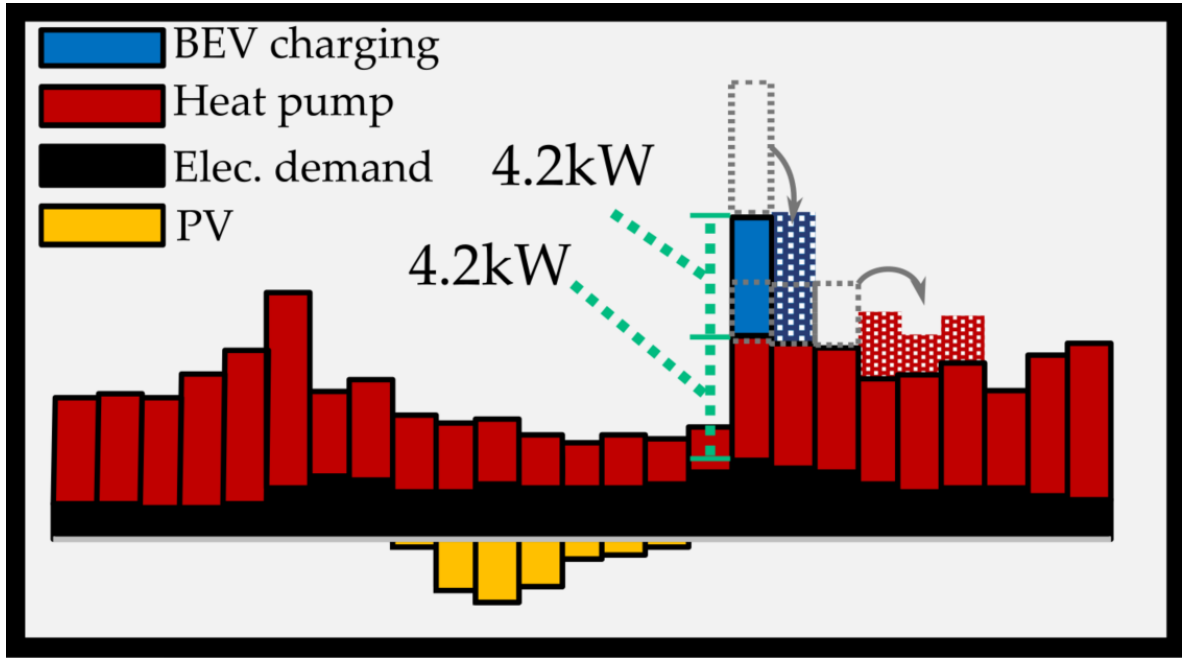
Capacity tariffs in force in Belgium since 2023 [6]

DSO-side downregulation of heat pumps & wall boxes (*§14a regulation*) by 2024 in Germany [4]

DSO-side downregulation in Germany (EnWG §14a)

- Allowing DSOs to downregulate controllable loads (e.g. heat pump/wall boxes) down to **4.2 kW** in case they cause behavior that threatens grid stability
- Planned to come into force in 2024
- (No direct compensation of the consumer for the downregulation)
- (A complementary measure to grid reinforcement, not an alternative)

Example case of DSO-side downregulation

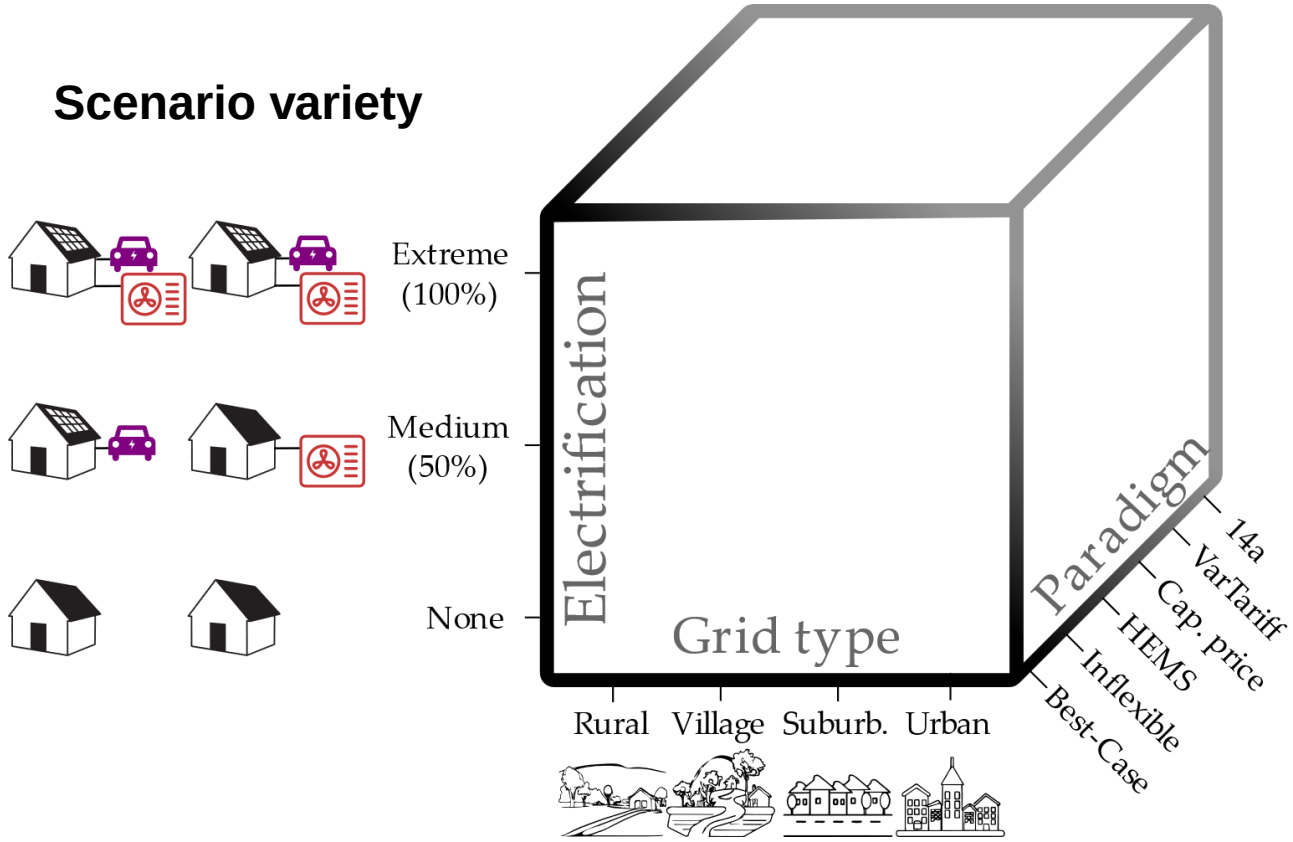


Goal of the study

Optimization (MILP)-based LV modeling framework for identifying

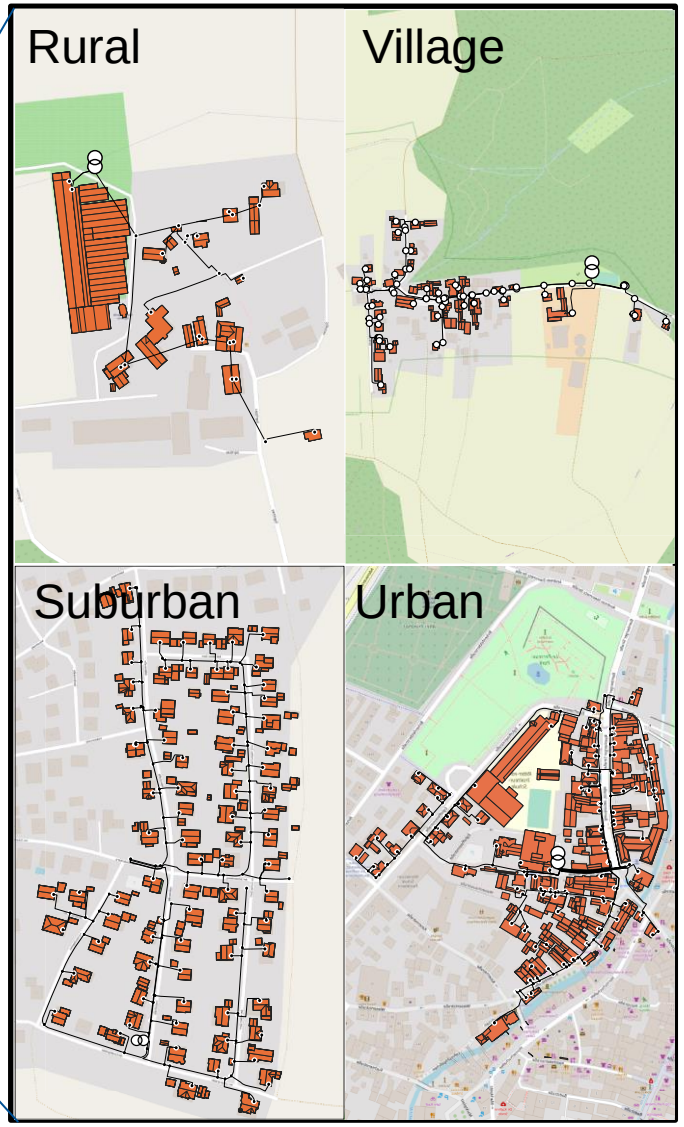
- The necessity of LV grid reinforcement under high electrification scenarios
  (50% & 100% of heating and mobility)

- Grid-relieving potential of various techno-economic measures, with a focus on
  - **capacity tariffs** and
  - **DSO-side downregulation (14a)**



Case study

- Four LV grids in a Southern German town
- **Rural**, **village**, **suburban,** and **urban** characteristics
- Localized demand and potential characteristics for **electricity**, **heating**, and **mobility**
- Both the **yearly variations** and an **extreme winter week** considered

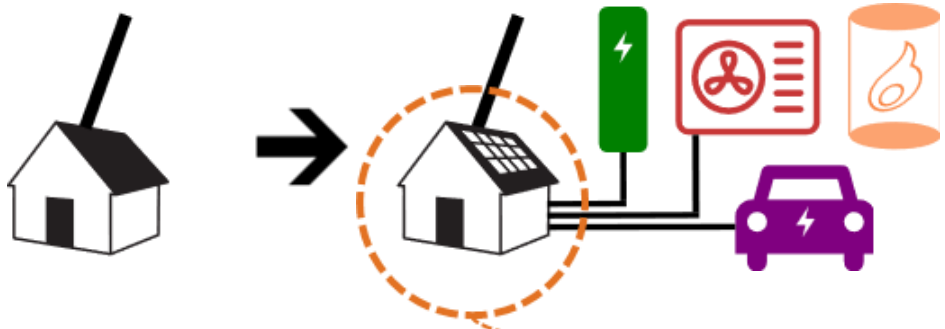


LV system optimization framework

System optimized as a **sequential game** between the prosumers and DSO

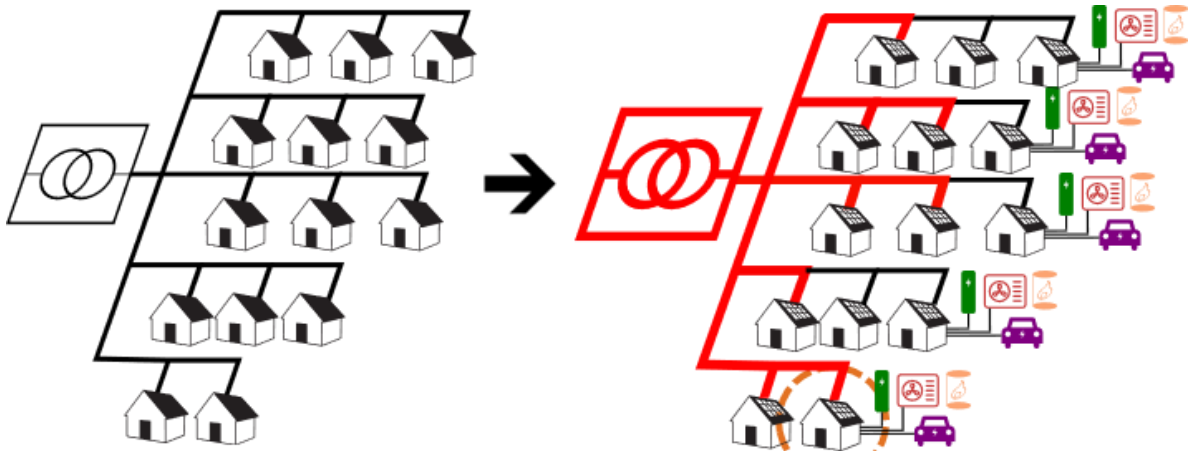
1. Prosumer optimization models
for the optimal dimensioning and operation of distributed energy resources (DERs):

- PV,
- heat pump with auxiliary heating unit,
- BEV charging,
- battery storage,
- thermal storage

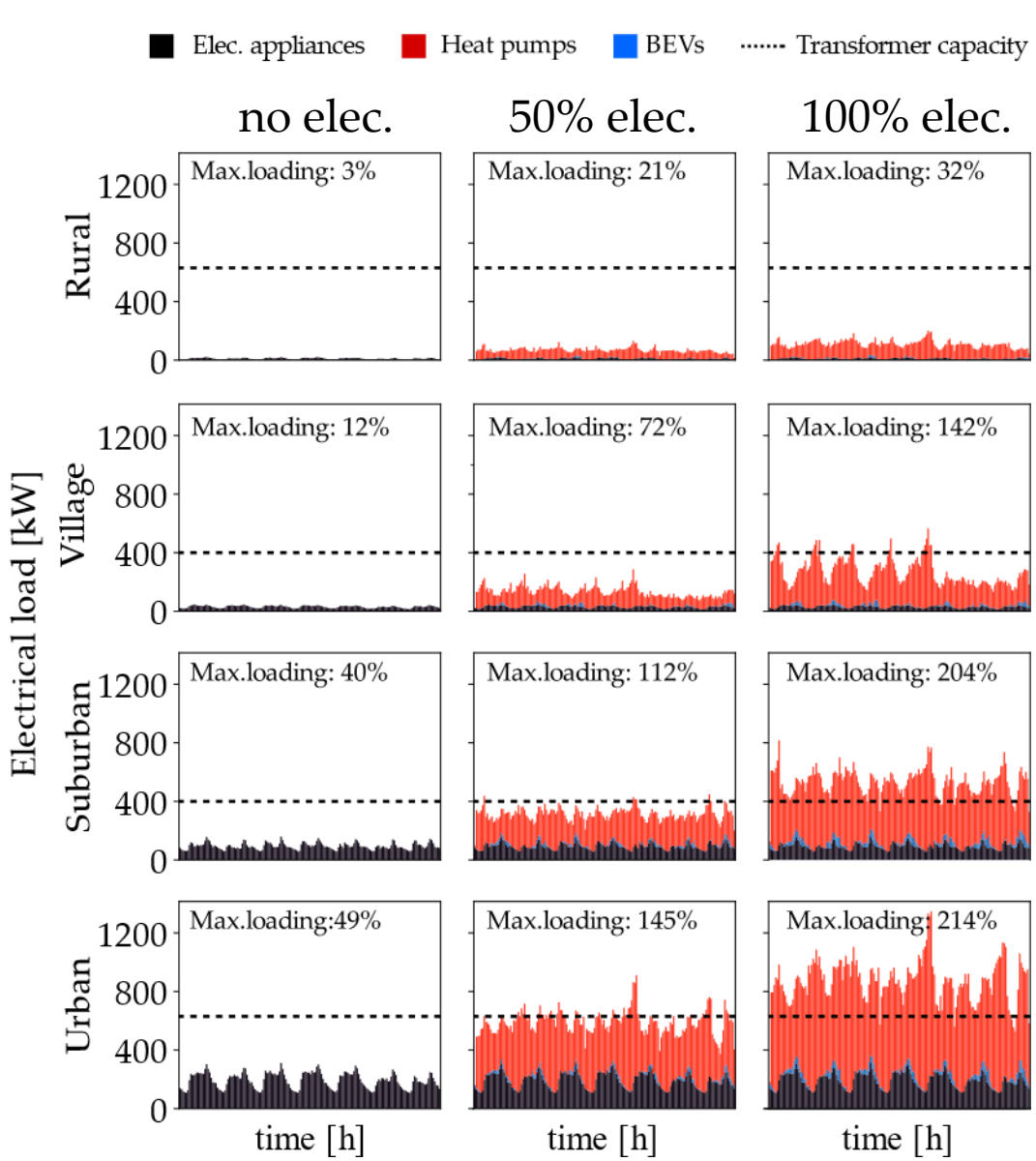


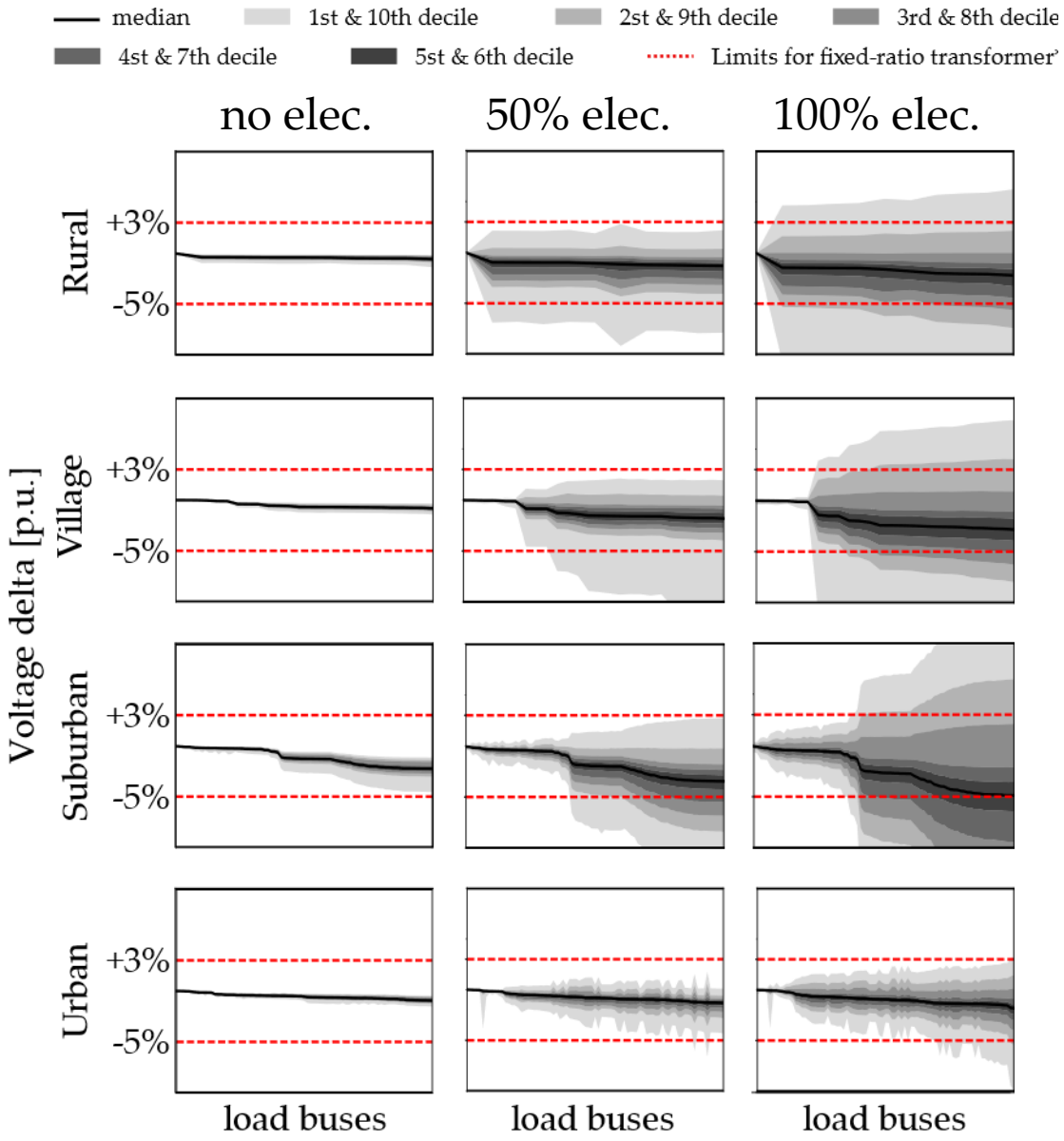
2. Grid optimization model
for satisfying demand and feed-ins while respecting the grid capacities

Grid reinforcement options:
- parallel cabling
- transformer replacement



New loads lead to a need of reinforcement

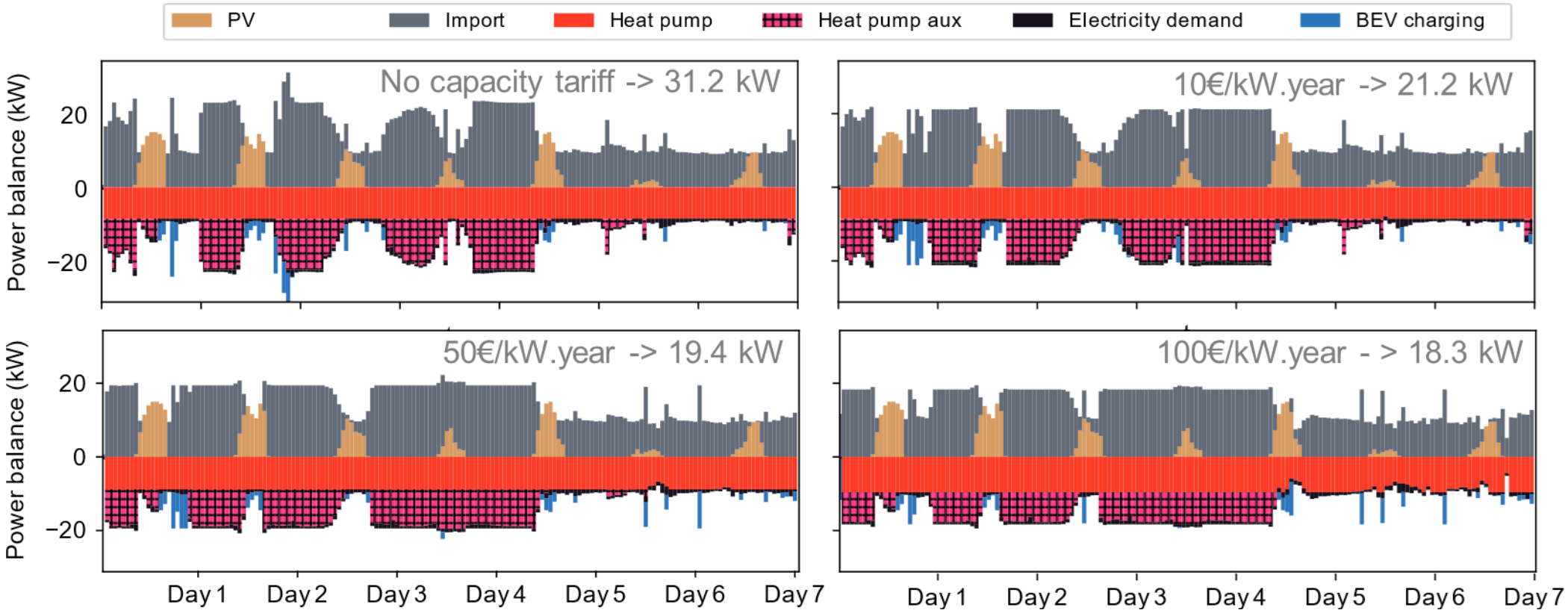




Effects of capacity pricing

Example building (2), village with 100% electrification, extreme winter week

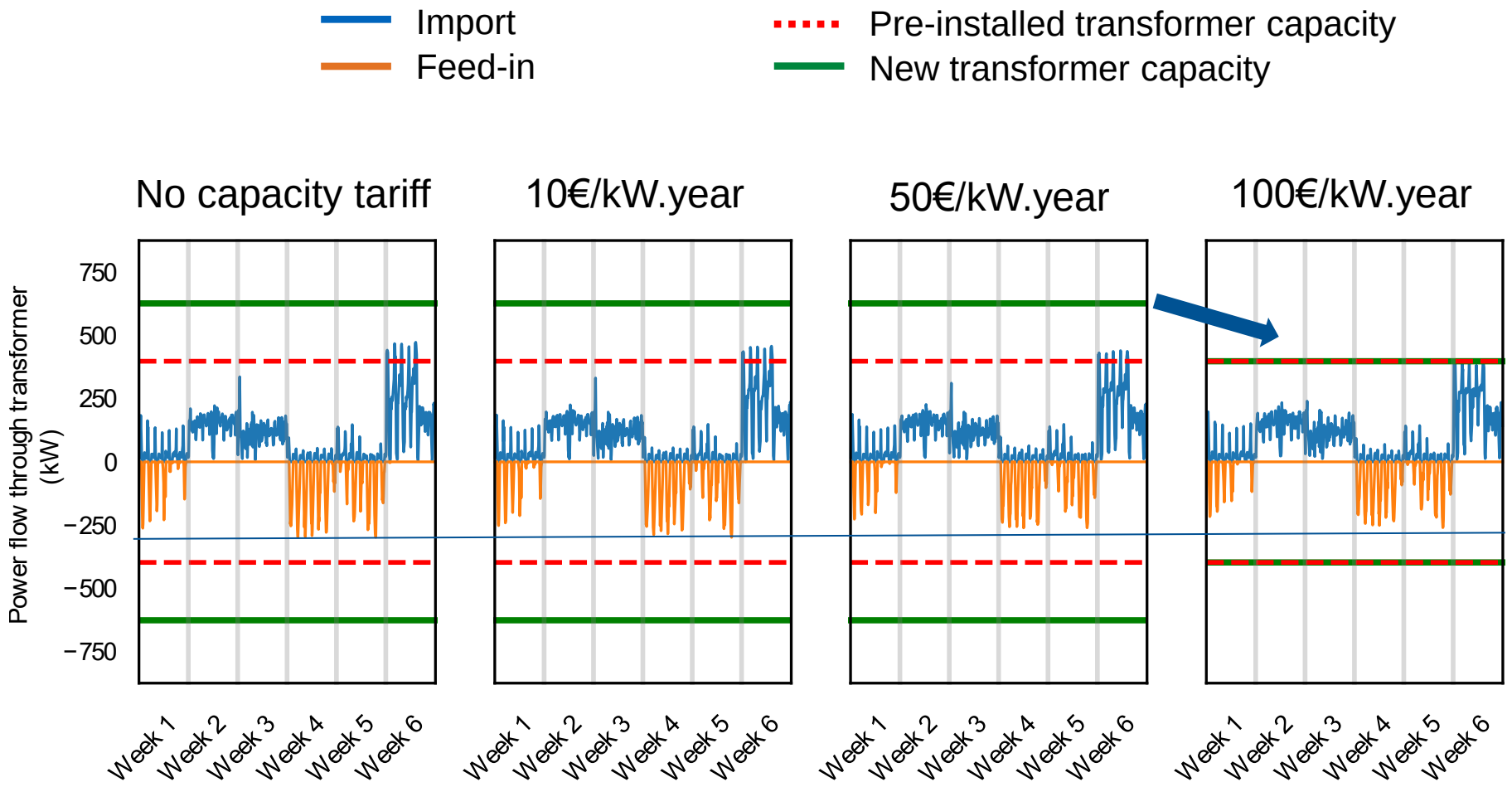
- Three capacity tariff (CT) levels (10, 50, 100€/kW.year)
- Prosumers can dimension and react by using flexibilities
- Low CT -> low-hanging fruits (BEV charging)
- Higher CTs -> optimal capacities start to change



Effects of capacity pricing

Example region, village with 100% electrification

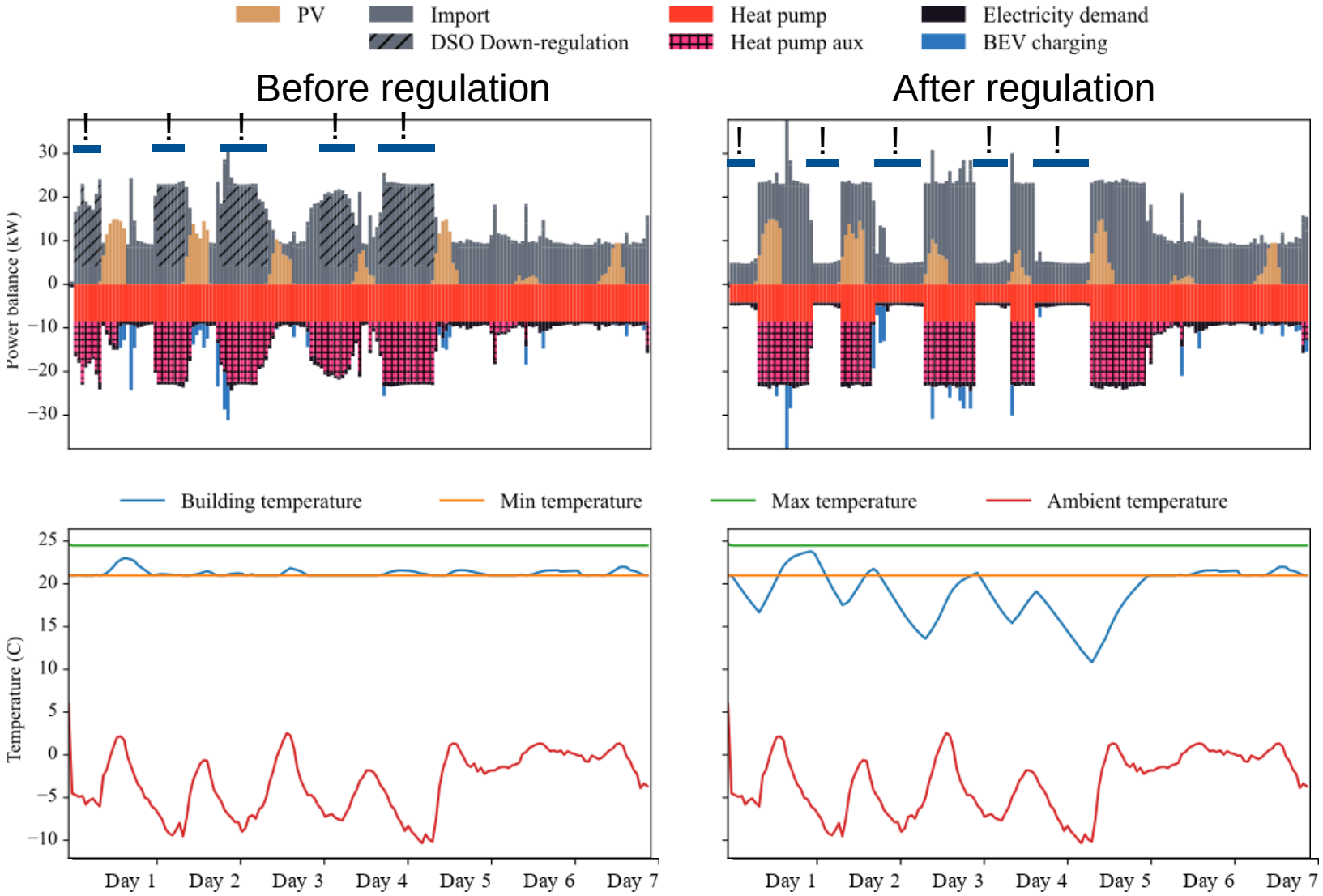
- Capacity pricing relevant for the winter period behavior
- Transformer replacement avoided with CT of 100€/kW (Reference: In Belgium around 40€/kW currently)



Effects of DSO-side downregulation

Example building (2), village with 100% electrification, extreme week

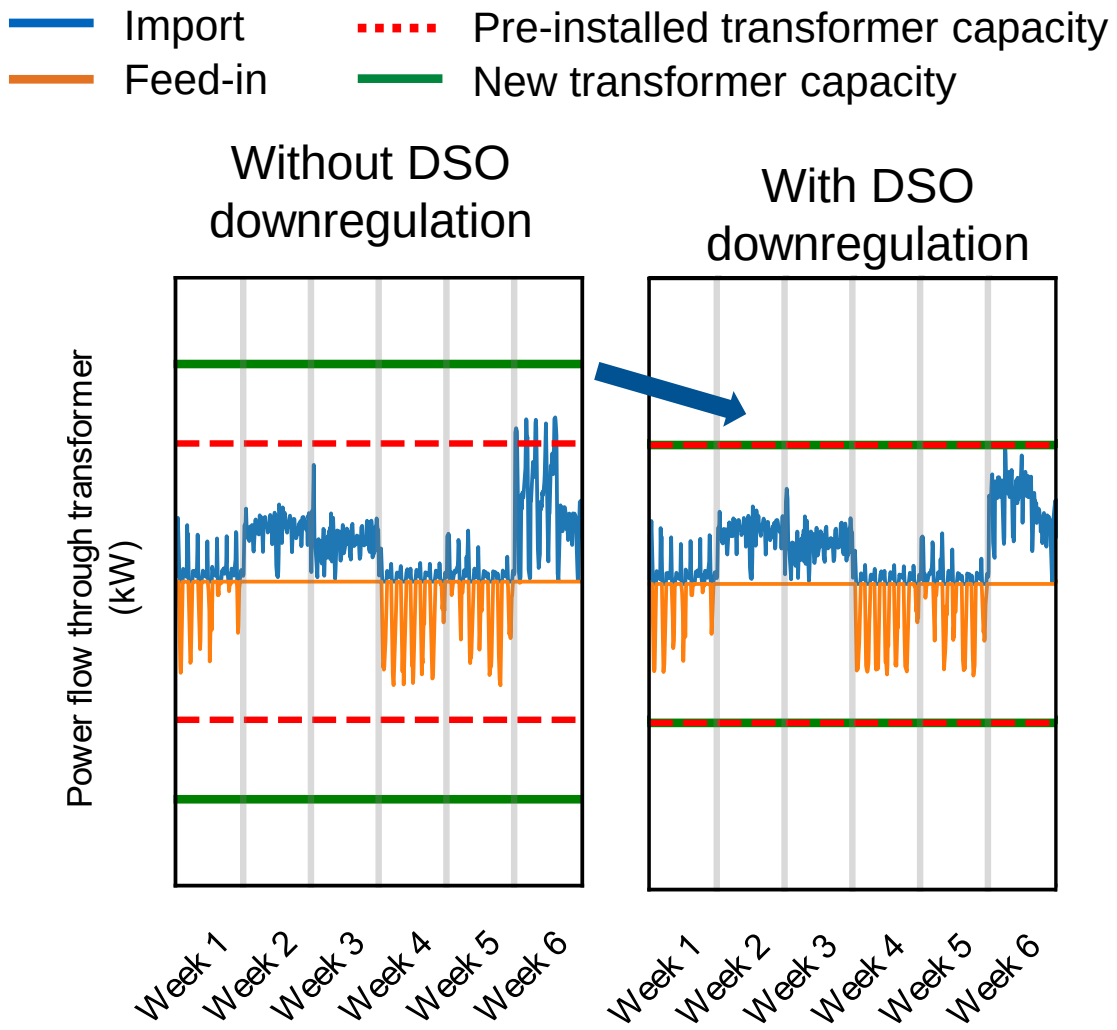
- Multi-family house heavily downregulated
- Shifting of heat pump demand to non-regulated hours
- Substantial violation of temperature limits!



Effects of DSO downregulation

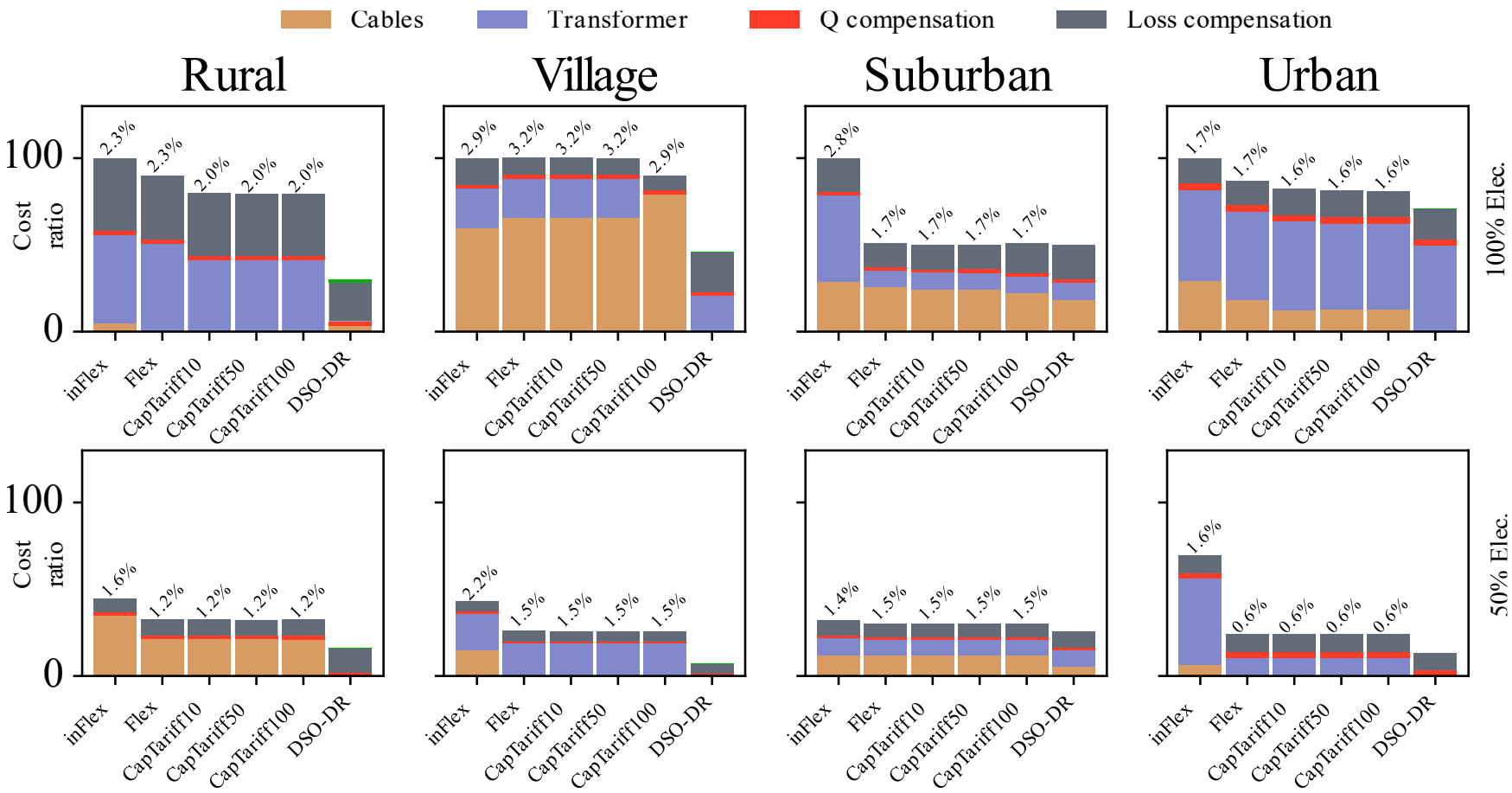
Example region, village with 100% electrification

- Downregulation leads to a reliable reduction of the grid peaks
- Rebound effects should be considered by DSOs



Cost breakdown

- Low potential of capacity tariffs for reducing grid reinforcement needs (low flexibility in the winter week)
- DSO downregulation reliably reduces the necessary grid reinforcement across all scenarios
- Despite volatile grid costs, relatively low share w.r.t. other system costs! (1-3%)



Takeaways

- For heat pump-dominated settings, the behavior of prosumers in the **extreme winter times** is decisive for grid reinforcement needs

- Grid costs are subordinated compared to overall system costs, making an eventual grid reinforcement not only unavoidable but also economically acceptable **in the long term**

- A combination of other techno-economic measures may assist in controlling the peaks in the **short- to medium-term**

- There is no **„silver bullet“**, each LV system have individual challenges

References

[1] German Federal Network Agency. Approval of the scenario framework 2023-2037/2045 (de: *Genehmigung des Szenariorahmens 2023-2037/2045*). 7.2022.

[2] Jessica Bateman. Heat pump installation plans may overburden Germany's grid - energy industry. CleanEnergyWire. 2023.

[3] Kerstine Appunn. Next German government's key climate and energy plans in 2021 coalition agreement. CleanEnergyWire. 2021.

[4] German Federal Network Agency. Determination for the implementation of the grid-oriented control of controllable consumption devices and controllable grid connections in accordance with § 14a EnWG (de: *Festlegung zur Durchführung der netzorientierten Steuerung von steuerbaren Verbrauchseinrichtungen und steuerbaren Netzanschlüssen nach § 14a EnWG*). 2023.

[5] German Federal Parliament. Energy Industry Act § 41a Load-variable, time-of-day-dependent or dynamic and other electricity tariffs (de: *Energiewirtschaftsgesetz § 41a Lastvariable, tageszeitabhängige oder dynamische und sonstige Stromtarife*). EnWG

[6] Flemish regulator of the electricity and gas market. How much capacity tariff do you pay for a kilowatt? (nl: *Hoeveel capaciteitstarief betaalt u voor een kilowatt?)* | VREG. 2023.